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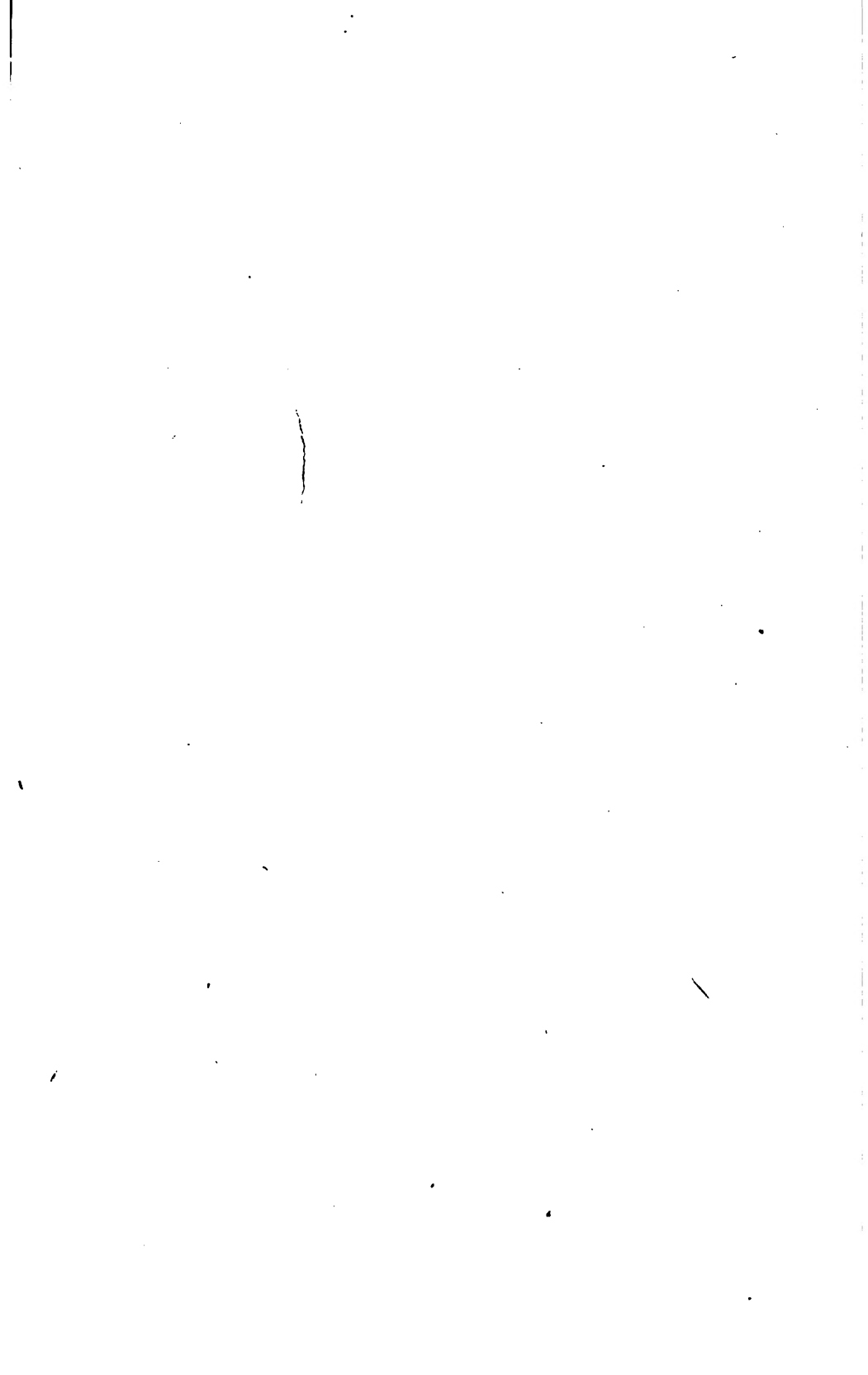
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# **Bi-Monthly Bulletin**

OF THE

# **American Institute of Mining Engineers.**



**PUBLISHED BY THE AMERICAN INSTITUTE OF MINING ENGINEERS**

**At S-W. Cor. Seventh and Cherry Sts.**

**PHILADELPHIA, PA.**

**EDITORIAL OFFICE AT 29 WEST 39TH STREET, NEW YORK, N. Y.**

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# BI-MONTHLY BULLETIN

OF THE

## AMERICAN INSTITUTE OF MINING ENGINEERS.

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No. 16

JULY

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*Subscription (including postage), \$10 per annum; to members of the Institute, public libraries, educational institutions and technical societies, \$5 per annum.*

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# TABLE OF CONTENTS.

## SECTION I. INSTITUTE ANNOUNCEMENTS.

	PAGE
Bi-Monthly Bulletin, . . . . .	iii
List of Officers for the Year Ending February, 1908, . . . . .	iv
Toronto Meeting, . . . . .	v
Collective Index of the <i>Transactions</i> , Vols. I. to XXXV., inclusive, . . . . .	vii
Library, . . . . .	viii
Membership, . . . . .	xx
Candidates for Membership, . . . . .	xxiii
Change of Address of Members, . . . . .	xxv
Address Wanted, . . . . .	xxxix

## SECTION II. TECHNICAL PAPERS.

No. 1. HENRY M. HOWE and BRADLEY STOUGHTON. The Influence of the Conditions of Casting on Piping and Segregation, as Shown by Means of Wax Ingots, . . . . .	561
No. 2. J. E. JOHNSON, JR. Discussion of Mr. Meissner's Paper, Notes on the Gayley Dry-Air Blast Process, . . . . .	575
No. 3. R. GILMAN BROWN. The Vein-System of the Standard Mine, Bodie, California, . . . . .	587
No. 4. GEORGE A. PACKARD. Discussion of Mr. Hofman's Paper, Laboratory Experiments in Lime-Reasting a Galena-Concentrate, . . . . .	603
No. 5. R. W. HUNT, F. BEUTTER and H. M. HOWE. Discussion of Mr. Howe's Paper, Piping and Segregation in Steel Ingots, . . . . .	609
No. 6. W. D. VERSCHOYLE. The Verschoyle Pocket Transit, . . . . .	617
No. 7. CHARLES CATLETT. Barite Associated with Iron-Ore in Pinar del Rio Province, Cuba, . . . . .	623
No. 8. PERSIFOR FRAZER. Bibliography of Injuries to Vegetation by Furnace-Gases, Supplementary Note, . . . . .	625
No. 9. ROBERT H. RICHARDS. The Wilfley Table, . . . . .	627
No. 10. JOHN BIRKINBINE. Biographical Notice of William George Neilson, . . . . .	653
No. 11. BIOGRAPHICAL NOTICES OF 1906, . . . . .	657
No. 12. HENRY M. HOWE. Discussion of Mr. Mathewson's Paper, Relative Elimination of Iron, Sulphur, and Arsenic in Bessemerizing Copper-Mattes, . . . . .	689

## ERRATA.

Corrections to *Bi-Monthly Bulletin*, No. 15, May, 1907.

Page 547, lines 11 and 12. For "Sutter creek" read "the South Fork of the American river, at Coloma, 35 miles from Sutter's Fort."

Page lxiii. Insert in list of representatives of engineering and scientific societies, "Österreicher Ingenieur- und Architekten-Verein, George W. McNulty."

## BI-MONTHLY BULLETIN.

### SECTION I.—INSTITUTE ANNOUNCEMENTS.

This section contains announcements of general interest to the members of the Institute, but not always of sufficient permanent value to warrant republication in the volumes of the *Transactions*.

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### SECTION II.—TECHNICAL PAPERS AND DISCUSSIONS.

[The American Institute of Mining Engineers does not assume responsibility for any statement of fact or opinion advanced in its papers or discussions.]

A detailed list of the papers contained in this section is given in the Table of Contents.

For the convenience of persons who desire to file, or otherwise use separately, the technical papers in Section II. of the Bulletin, each of these papers has been paged and wired by itself; the whole collection being held together by a single, heavy wire, upon the removal of which it will fall apart into individual pamphlets, substantially like those formerly issued.

A small stock of separate pamphlets, duplicating the technical papers given in Section II. of this Bulletin, is reserved for those who desire extra copies of any single paper.

Comments or criticisms upon all papers given in this section, whether private corrections of typographical or other errors or communications for publication as "Discussions," or independent papers on the same or a related subject, are earnestly invited.

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All communications concerning the contents of this Bulletin should be addressed to Dr. Joseph Struthers, Assistant Secretary and Editor, 29 W. 39th St., New York City (Telephone number 4600 Bryant).

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\* SECRETARY'S NOTE.—The Council is the professional body, having charge of the election of members, the holding of meetings (except business meetings), and the publication of papers, proceedings, etc. The Board of Directors is the body legally responsible for the business management of the Corporation, and is therefore, for convenience, composed of members residing in New York.

## THE TORONTO MEETING.

As already announced, the XCIIIrd meeting of the Institute will be held at Toronto, beginning July 23, 1907. Hotel Headquarters will be at the King Edward Hotel, in which also the sessions will be held. The Queens, Rossin, Wallen, Iroquois and Palmer are good hotels not far from the King Edward. Members must secure their hotel-accommodations beforehand, by direct correspondence with the hotel they select. For those who neglect this precaution, the Local Committee will doubtless do what it can, but is unable to promise anything.

Correspondence concerning this meeting (including notices of intention to attend it) should be addressed hereafter exclusively to Mr. W. G. Miller, Provincial Geologist, Bureau of Mines, Toronto, who is the representative of the Local Committee.

The excursion to Cobalt, Lake Tenagami, Sudbury, etc., arranged by that Committee, involves the use of a special Pullman train for meals and lodging. After waiting a reasonable time to hear from members, the Local Committee has made its contract for Pullman cars. According to its latest report, there was still room for additional excursionists. Under this head, application made immediately to Mr. Miller may not be too late.

Sessions for the presentation of papers, etc., will be held at the King Edward Hotel on Tuesday afternoon, July 23, and Wednesday morning and afternoon, July 24. The following papers have been accepted:

1. Some Reflections on Secrecy in the Arts, by James Douglas, New York, N. Y.
2. The Wilfley Table, by R. H. Richards, Boston, Mass.
3. The Tar-Sands of the Athabaska District, by Robert Bell, Ottawa, Can.
4. The Occurrence of Nickel in Virginia, by Thomas L. Watson, Blacksburg, Va.
5. Coal-Briquetting in the United States, by E. W. Parker, Washington, D. C.



6. The Temple-Ingersoll Electric-Air Rock-Drill, by W. L. Saunders, New York, N. Y. (Illustrated with lantern-views.)

7. Notes on the Cobalt and Sudbury Mineral Areas, by Willet G. Miller, Toronto, Can. (Illustrated with lantern-views.)

8. Geology of the Virginia Barite-Deposits, by Thomas L. Watson, Blacksburg, Va.

9. The Effect of High Litharge in the Crucible-Assay for Silver, by Richard W. Lodge, Boston, Mass.

10. Physical Factors in the Metallurgical Reduction of Zinc Oxide, by Woolsey McA. Johnson, New York, N. Y.

11. Zinc-Oxide in Iron-Ores, and the Effect of Zinc in the Iron Blast-Furnace, by John J. Porter, Cincinnati, Ohio.

12. Chronology of Lead-Mining in the United States, by Walter R. Ingalls, New York, N. Y.

13. The Promontorio Mine, by Francis C. Lincoln, New York, N. Y.

14. Blow-Holes in Steel Ingots, by E. von Maltitz, South Chicago, Ill.

15. The Evergreen Copper-Deposit, by Etienne A. Ritter, Colorado Springs, Colo.

16. Pure Coal as a Basis for the Comparison of Bituminous Coals, by W. F. Wheeler, Urbana, Ill.

17. Quantitative Field-Test for Magnesia in Cement-Rock and Limestone, by Charles Catlett, Staunton, Va.

18. The Production of Converter-Matte from Copper-Concentrates by Pot-Roasting and Smelting, by George A. Packard, Boston, Mass.

19. Biographical Notices of 1906.

20. The Panoramic Camera Applied to Photo-Topographic Work, by Charles W. Wright, Washington, D. C.

21. Notes on the Present Source and Uses of Vanadium, by J. Kent Smith, Pittsburg, Pa.

22. The Mines of San Juan Depomuceno del Doctor, by T. D. Murphy, Mexico City, Mex.

23. Discussion of Paper by H. M. Howe on Piping and Segregation in Steel Ingots, by Alfred C. Lane, Lansing, Mich.

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Of these papers, Nos. 1 to 7 will probably be presented in full or in oral abstract by their authors.

**COMPLETE ANALYTICAL AND ALPHABETICAL INDEX OF VOLS. I.—XXXV.,  
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Any person discovering a mutilation or defect in any book of the libraries is requested to report it to the librarian on duty.

### Accessions.

From May 1 to July 1, 1907.

### **Amalgamated Society of Engineers, London.**

AMALGAMATED SOCIETY OF ENGINEERS. *Annual Report*, 56th.  
8vo. London, 1907.

**H. C. Beeler.**

*Prospecting in the Black Rock Long Creek Vicinity near the Sweetwater River, Fremont County, Wyoming.* 12 p. map. 8vo. Cheyenne, 1907.

**H. T. Blake, New Haven, Conn.**

*Medallion of Eli Whitney Blake.*

**Boston Society of Civil Engineers.**

BOSTON SOCIETY OF CIVIL ENGINEERS. *List of Members,* 1907. 8vo.

**Bennett H. Brough.**

BROUGH, B. H. *A Treatise on Mine-Surveying.* Ed. 12. xvi, 372 p. pl. 8vo. London, 1906.

[SECRETARY'S NOTE.—The first edition of this well-known text-book appeared, I believe, in 1888, when the author was still instructor in Mine-Surveying at the Royal School of Mines in London. A few years later he left this position to assume that of Secretary of the Iron and Steel Institute, which he has occupied ever since, with great credit to himself, and corresponding benefit to the illustrious society, the publications of which he conducts. The position of Secretary and executive manager of such an organization, not less (perhaps even more) than that of a technical instructor, keeps a man in touch with both the literature and the practice of many branches of engineering, and especially with that which he has previously made his specialty. It is not surprising, therefore, that Prof. Brough's excellent manual has reached, since 1888, its twelfth edition, having been repeatedly revised and brought up to date by its vigilant and competent author. The eleventh edition, issued in 1904, was characterized, in particular, by new accounts of Ferguson's cyclograph for exploratory surveys, Pollitzer's method of shaft-surveying, Justice's surveys of bore-holes in South Africa, and the Thomson-Thalen instruments for the magnetic survey of iron-ore deposits. The twelfth edition, besides having been again revised as to former contents, contains references to later literature and descriptions of recent experiences and inventions, among which may be named Marriott's surveys of bore-holes in the Transvaal, the use of the Meyer-Wiesmann tocheometer at the Simplon tunnel, the Hammer-Fennel tocheometer, Burr's method of surveying with stretched strings, magnetic observations in the deep Transvaal shaft, Lake Superior, etc. That Prof. Brough has not omitted to notice the writings and inventions of American engineers, is shown by the excellent bibliography and alphabetical index which completes the value of his book for students as well as practitioners.—R. W. R.]

**Canada—Mines, Superintendent of.**

*Report on the Experiments Made at Sault Ste. Marie, Ont., in the Smelting of Canadian Iron-Ores by the Electro-Thermic Process,* by E. Haanel. 149 p. pl. 8vo. Ottawa, 1907.

**Carnegie Library of Pittsburg.**

PITTSBURG—CARNEGIE LIBRARY. *Classified Catalogue.* Vols. 1-3. 8vo. Pittsburg, 1907.

**Carnegie Library of Pittsburg.**

PITTSBURG—CARNEGIE LIBRARY. *Annual Report*, 10th. 8vo. Pittsburg, 1906.

*Iron*. Vols. 1-13. f°. London, 1873-'79.

*Index to Proceedings of the Engineers' Society of Western Pennsylvania*. Vols. 1-20, 1880-'94. 8vo. Philadelphia, 1894.

——— *Monthly Bulletin*. Vol. 11; vol. 12, Nos. 1-4. 8vo.

——— *Story Hour Courses for Children from Greek Myths*. 29 p. 8vo. Pittsburg, 1906.

**Century Association.**

CENTURY ASSOCIATION. *List of Members*, 1906. 8vo. New York, 1907.

**Department of Lands and Mines of British Guiana.**

BRITISH GUIANA—DEPARTMENT OF LANDS AND MINES. *Preliminary Report on the Geology of the Lower Essequibo River, the Groete Creek District, and the Lower Cuyuni River*. 12 p. f°. Georgetown, 1903.

——— *Report on the Geology of the Cuyuni River, from Arawak Matope to the Akarabisi Creek*. 19 p. f°. Georgetown, 1905.

——— *Report on the Petrography of the Cuyuni and Mazaruni Districts, and of the Rocks at Omai, Essequibo River*. 71 p. f°. Georgetown, 1905.

**Department of Mines of New South Wales.**

NEW SOUTH WALES—DEPARTMENT OF MINES. *Annual Report*, 1906, 1907. f°. Sydney, 1907.

**Joseph Dixon Crucible Company.**

*Photograph of John A. Walker*.

**Anton Eilers.**

*Berg- und-Hüttenmännische Zeitung*. Vols. 36, 41, 45, 46, 47. 4to. Leipzig, 1877, 1882, 1887, 1888.

**Engineering and Mining Journal.**

AACHEN—KÖNIGLICHE TECHNISCHE HOCHSCHULE. *Programm*, 1906-'07. 8vo. Aachen, 1906.

ALABAMA—GEOLOGICAL SURVEY. *Underground Resources of Alabama*, by E. A. Smith. xvi, 388 p. pl. map. 8vo. Montgomery, 1907.

AUSTRIA—K. K. HANDELSMINISTERIUM. *Statistik des Auswartigen Handels des Osterreichisch Ungarischen Zollgebiets*. Vol. 1, pt. 1, and vol. 3, 1904. 8vo. Wien, 1905.

**Engineering and Mining Journal.**

BARTOCCINI, A. *Coal and Iron Mines*. 155 p. il. 8vo. Monterrey, 1906.

BELGIUM—MINISTERIUM DES FINANCES ET DES TRAVAUX PUBLICS. *Statistique*, 1904. f°. Bruzelles, 1904.

CALIFORNIA—STATE MINING BUREAU. *Report of the Board of Trustees*, 1906. 8vo. San Francisco, 1906.

CANADA—GEOLOGICAL SURVEY. *Annual Report*. Vols. 14, 15 and maps. 8vo. Ottawa, 1901-'03.

CANADA—MINES, SUPERINTENDENT OF. *Report on the Experiments Made at Sault Ste. Marie, Ont., in the Smelting of Canadian Iron Ores by the Electro-Thermic Process*, by Eugene Haanel. 149 p. pl. 8vo. Ottawa, 1907.

CONNECTICUT—BUREAU OF LABOR STATISTICS. *Report*, 1906. 8vo. Hartford, 1906.

CONNECTICUT—STATE GEOLOGICAL AND HISTORY SURVEY. *Bulletin* Nos. 6, 7, 9. 8vo. Hartford, 1906-'07.

EPHRAIM, J. *Deutsches Patentrecht für Chemiker*. xxvii, 608 p. 8vo. Halle a. S., 1907.

CURLE, J. H. *Gold Mines of the World*. Ed. 3. 10,308 p. 8vo. London, 1905.

[SECRETARY'S NOTE.—The first edition of this book, if my impression is correct, was issued not far from 15 years ago. The second edition, published in 1902, contained the results of a supplementary personal inspection of mines in practically all the gold-producing districts of the world, except Siberia. This third edition, published in 1905, is declared to have been "almost entirely rewritten." The simple statement of these facts shows the impossibility of presenting at any given time a comprehensive report of this subject which will remain for a considerable period authoritative. Fresh discoveries and developments, improvements in mining and metallurgy, commercial changes, creating new markets or making old ones more accessible—these and many other continually changing conditions require a continual re-statement of descriptions, opinions and prophecies. It is not many years since we were informed, on high scientific authority, that the world's product of gold had reached its maximum—a verdict which was widely published and effectually used by the "free silver" party in this country. But, in "Hans Breitmann's" phrase, "vere is dot barty now?" Its leader can only say that the question once regarded as instant and vital has been rendered obsolete by the unexpected interference of Providence, in enormously increasing the annual supply of gold.

This consideration does not impugn the value of such contemporary reviews of gold-mining as Mr. Curle's, though it does emphasize the advisability of getting the very last edition of a work of that class, even when one possesses the last but one. No doubt it is a pity that our professional books will not remain permanently authoritative and conclusive; but, after all, to a mining engineer, what is the cost of the very latest knowledge of a given district, compared with its value?



It is only fair to add, that Mr. Curle's book, besides its contemporaneous descriptions and estimates of gold-mining enterprises and conditions in many countries, contains a good deal in the way of practical suggestion concerning the examination and valuation of undeveloped mining-ground, or mines already in operation, which may be studied with profit by all experts, and will, in the main, not lose its value through the lapse of time.—R. W. R.]

### Engineering and Mining Journal.

GEOLOGICAL SURVEY OF ENGLAND AND WALES. *Geology of Falmouth and Truro and of the Mining District of Camborne and Redruth*, by J. B. Hill and D. A. MacAlister. x, 335 p. pl. 8vo. London, 1906.

GRONDAL KJELLIN COMPANY, LTD. *Concentration and Briquetting of Iron Ores*. 17 p. il. 4to. n. p., n. d.

IOWA GEOLOGICAL SURVEY. *Annual Report*. Vol. 16. 4to. Des Moines, 1906.

IRON AND STEEL INSTITUTE. *Presidential Address by Sir H. Bell, May, 1907*. 8vo. London, 1907.

ITALY—REALE COMITATO GEOLOGICO. *Relazione del direttore de della carta Geologica . . .* 1904. 8vo. Roma, 1905.

——— *Memorie Descrittive della Carta Geologica d'Italia*. Vol. 18. 8vo. Roma, 1900.

*Jahrbuch der Österreichischen Berg- und-Hüttenwerke, Maschinen und Metallwarenfabriken von R. Hanel*, 1906. 8vo. Wien, 1906.

KENTUCKY—GEOLOGICAL SURVEY. *Bulletin* No. 4. 8vo. Louisville, 1905.

LESLEY, R. W. *Concrete Factories*. 152 p. il. 8vo. New York, n. d.

MICHIGAN—BUREAU OF LABOR AND INDUSTRIAL STATISTICS. *Annual Report*, 21st, 23d. 8vo. Lansing, 1904, 1906.

MICHIGAN—GEOLOGICAL SURVEY. *Annual Report*, 1903. 8vo. Lansing, 1903.

MEXICO—ESTADO Y DEL DESPACHO DE HACIENDA Y CREDITO PUBLICO, SECRETARIA. *Boletín de Estadística Fiscal*. Nos. 262, 269, 271, 272, 274. 4to. Mexico, 1904, 1905.

NELSON, S. A. *Consolidated Stock Exchange of New York*. ix, 124 p. 8vo. New York, 1907.

NEW JERSEY—GEOLOGICAL SURVEY. *Annual Report of the State Geologist*, 1905. 8vo. Trenton, 1906.

**Engineering and Mining Journal.**

NEW JERSEY—STATISTICS, BUREAU OF. *Annual Report of the Bureau of Statistics of Labor and Industries, 1906.* Trenton, 1906.

OBERSCHLESISCHEN BERG UND HÜTTENMANNISCHEN VEREINS. *Zeitschrift.* Vol. 45, April–June, 1906. Kattowitz, 1906.

PETERS, E. D. *Principles of Copper Smelting.* ix, 612 p. 8vo. New York–London, 1907.

[SECRETARY'S NOTE.—My somewhat extended review of this work in the *Engineering and Mining Journal* of April 27, 1907, explains and illustrates the following brief statement. It is not a new edition of Prof. Peters's well-known "Modern Copper Smelting" or a compilation of the records of practice; but a manual of the methods of reasoning in its special field, containing very few quotations, descriptions of plant or apparatus, or details which can be obtained from other books, even the author's own. To an almost unique degree, it is, from beginning to end, original. Two chapters should be excepted from this statement, Chap. VIII., on Pyrite-Smelting, which is practically the work of Mr. Robert C. Sticht, of Broken Hill, Australia, and Chap. XIV., on Applications of Thermo-Chemistry, contributed by Prof. Jos. W. Richards, of Lehigh University. No one acquainted with the standing of these two as authorities on the subjects of which they treat will fail to be grateful for these chapters. The rest of the book, an expanded and carefully revised reproduction of Prof. Peters's lectures to his students at the Harvard Scientific School, is admirably stimulating and suggestive, to practitioners as well as pupils. It deals most instructively with the principles of smelting in general, as a process primarily of concentration with incidental chemical changes; the principles and practice of preliminary roasting, matte-smelting, the calculation of slags, matte and its further treatment, and the principles of furnace-building.—R. W. R.]

REDWOOD, BOVERTON. *Petroleum Handbook.* Ed. 2. 2 vols. 8vo. London, 1906.

[SECRETARY'S NOTE.—This is the second edition of the great work issued first in 1896 by the distinguished author. He has been assisted in its preparation by a considerable number of eminent experts, with whose co-operation he has perfected and brought down to date a remarkably comprehensive and accurate account, treating successively and with abundant detail the history of the petroleum industry; the geological and geographical distribution of petroleum and natural gas; their physical and chemical properties; their origin; their production (together with that of ozokerite); the refining of petroleum; the industry of shale-oil and allied industries; the transport, storage and distribution of petroleum; the testing of crude petroleum and its products, and of other similar materials; their manifold uses; the statutory and other regulations concerning them; and the statistics of trade, tariffs, etc., which belong to the subject. The book is clearly and logically arranged, handsomely illustrated and adequately indexed, and Sir Boverton Redwood may well regard it as a worthy monument of his long, active and creditable career.—R. W. R.]

**Engineering and Mining Journal.**

RHODESIA—CHAMBER OF MINES. *Annual Report*, 11th. 8vo. Bulawayo, 1906.

SAUNDERS, W. E., PARLEE, N. W., and MACDONALD, BERNARD. *Mine Timbering*. xi, 179 p. 8vo. New York, 1907.

TRANSVAAL—CHAMBER OF MINES. *Report*, 13th. 8vo. Johannesburg, 1903.

U. S.—GEOLOGICAL SURVEY. *Bulletin* Nos. 279, 286, 296, 300, 302, 305, 310. 8vo. Washington, 1906, '07.

——— *Monograph*. Vol. 50. f°. Washington, 1906.

——— *Professional Paper* No. 57. f°. Washington, 1907.

——— *Water Supply and Irrigation Papers* Nos. 182, 183, 191. 8vo. Washington, 1906.

U. S.—INTERSTATE COMMERCE COMMISSION. *Annual Report*, 20th. 8vo. Washington, 1906.

WISCONSIN—GEOLOGICAL SURVEY. *Bulletin* No. 14, and atlas. 8vo. Madison, 1906.

**Engineering Magazine.**

ENGINEERING MAGAZINE. *Engineering Index*, 1906. 8vo. New York, 1906.

**Engineers' Club, New York City.**

*Architectural Record*. Vol. 3. 8vo. New York, 1894.

BUSBY, T. A. *Biographical Directory of Railway Officials of America*. 528 p. 8vo. Chicago, 1896.

*Engineering Magazine*. Vol. 1. 8vo. New York, 1892.

*The Forum*. Vol. 8. 8vo. New York, 1889.

INTERNATIONAL RAILWAY CONGRESS. *Proceedings*, 1895.

Vols. 1-2; 1901, vol. 1. 8vo. London, 1895, 1901.

——— *Bulletin*. Vol. 1-2, 1896; vol. 1-2, 1897; 1898, vol. 12, pt. 1. 8vo. Brussels, 1896-'98.

*Iron Age*. Vols. 44, 48. f°. New York, 1889, 1891.

*North American Review*. Vols. 151, 155. 8vo. New York, 1890, 1892.

*Nineteenth Century*. Vol. 28. 8vo. New York, London, 1890.

U. S. CONGRESS—HOUSE. *House Documents*. Vol. 82, 115. 8vo. Washington, 1900.

U. S. CONGRESS—SENATE. *Senate Documents*. Vol. 3, 4, 6. 8vo. Washington, 1897, 1899.

**Engineers' Society of Western Pennsylvania.**

*Chemical News.* Vols. 63-74. 4to. London, 1891-'96.

**Persifor Frazer.**

FRAZER, PERSIFOR. *Scientific Methods in the Study of Hand-writing.* p. 245-75. 8vo. Philadelphia, 1907.

**Geological and Natural History Survey of Wisconsin.**

WISCONSIN—GEOLOGICAL AND NATURAL HISTORY SURVEY.

*Clays of Wisconsin and Their Uses.* 8vo. Madison, 1906.  
(*Bulletin* No. 15.)

**Geological Survey of Iowa.**

IOWA—GEOLOGICAL SURVEY. *Annual Report.* Vol. 16.  
Des Moines, 1906.

**Geological Survey of Maryland.**

MARYLAND—GEOLOGICAL SURVEY. *Calvert County.* 227 p.  
8vo. Baltimore, 1907.

——— *St. Mary's County.* 209 p. 8vo. Baltimore, 1907.

**Hamilton Manufacturing Company.**

HAMILTON MANUFACTURING COMPANY. *Mechanical Loading in Mines.* unsp. 8vo. Columbus, 1907.

**J. L. Harrington.**

HARRINGTON, J. L. *Value of English to the Technical Man.*  
20 p. 8vo. Kansas, 1907.

**Institution of Mining and Metallurgy.**

INSTITUTION OF MINING AND METALLURGY. *Bulletin* No. 32.  
8vo. London, 1907.

**Jeffrey Manufacturing Company.**

JEFFREY MANUFACTURING COMPANY. *Care of Electric Mine Locomotive in Service.* (*Bulletin* No. 12.)

**John Crerar Library.**

JOHN CERERAR LIBRARY. *Annual Report, 12th.* 8vo. Chicago, 1907.

**William Kelly.**

MICHIGAN MINERAL STATISTICS. *Report, 1899.* 8vo. Lansing, 1899.

NEW YORK—STATE GEOLOGIST. *Report, 1893.* Vol. 1.  
8vo. Albany, 1893.

PENNSYLVANIA—INTERNAL AFFAIRS, DEPARTMENT OF. *Annual Report, pt. 3, 1884.* 8vo. Harrisburg, 1884.

**Königliche Technische Hochschule zu München.**

MÜNCHEN—KÖNIGLICHE TECHNISCHE HOCHSCHULE. *Bericht, 1905-'06.* 4to. München, 1907.

——— *Programm, 1906-'07.* 8vo. München, 1907.

**Lehigh University.**

HENSEL, W. U. *Wealth and Worth.* 44 p. 8vo. South Bethlehem, 1907.

**The Macmillan Company.**

SCHNABEL, CARL. *Handbook of Metallurgy.* Ed. 2, vol. 2. xvi, 867 p. il. 8vo. London, 1907.

[SECRETARY'S NOTE.—The first German edition of this Handbook, issued in 1874 and 1876, by Prof. Schnabel of Clausthal, supplied the general need of a modern compendium of metallurgy—aside from that of iron and steel, which had been treated separately by sundry eminent authors. But “modern” is a relative term; and Prof. Schnabel's second edition, published in 1902 and 1904, was a praiseworthy attempt to modernize the first. Both editions have found in Prof. Henry Louis, of the Durham College of Science, at Newcastle-upon-Tyne, not only a competent translator, but also an editor and co-laborer, qualified to add to their value by contributions from his own knowledge and experience. It is impossible to give in a brief notice any critical analysis of this work. Being necessarily a compilation from the technical literature of many countries, it must contain material of unequal value and authority. I will merely say here that Vol. I. (published in English in 1905) covered, with a considerable degree of completeness, down to 1902 (the date of the German original) the metallurgy of copper, lead, silver and gold; that Vol. II., here under consideration, is similarly complete to 1904 (when the German original appeared); and that both volumes contain valuable material of more recent date, for which our thanks are due to Prof. Louis.—R. W. R.]

**Metallgesellschaft und der Metallurgischen Gesellschaft A. G.**

METALLGESELLSCHAFT UND DER METALLURGISCHEN GESELLSCHAFT A. G. *Statistische Zusammenstellungen über Blei, Kupfer, Zink, Zinn, etc.* 13 Jahrgang, 1897–1906. 4to. Frankfurt am Main, 1907.

**Dr. Richard Moldenke.**

*Giesserei-Zeitung.* Vol. 1, Nos. 4, 6–19, 21, 22 and 24. 8vo. Berlin, 1904.

**Municipal Engineers of the City of New York.**

MUNICIPAL ENGINEERS OF THE CITY OF NEW YORK. *Constitution, By-Laws, List of Members, and Annual Report,* 1906. 8vo. New York, 1907.

**New York Edison Company.**

Framed photograph of the Engineering Building.

**T. A. Rickard.**

AUSTIN, L. S. *The Metallurgy of the Common Metals.* 407 p. il. 8vo. San Francisco, 1907.

**Smithsonian Institution.**

SMITHSONIAN INSTITUTION. *Smithsonian Physical Tables.* xxxiv, 301 p. 8vo. Washington, 1904.

**Society of Engineers.**

SOCIETY OF ENGINEERS. *Transactions*. Vol. 1906. 8vo. London, 1907.

**State Inspector of Mines of Idaho.**

IDAHO—STATE INSPECTOR OF MINES. *Annual Report of Mining Industry, 8th*. 8vo. Boise, 1906.

**State Library of Pennsylvania.**

PENNSYLVANIA STATE LIBRARY. *Report of the Librarian*, 1905. 8vo. Harrisburg, 1906.

**Dr. Joseph Struthers.**

CHAPMAN, R. H. *The Deserts of Nevada and Death Valley*. p. 48–97 il. 8vo. Washington, 1906.

WOOLSON, I. H. *Investigation of the Thermal Conductivity of Concrete and the Effect of Heat upon Its Strength and Elastic Properties*. p. 433–57 il. 8vo. n. p., 1906.

**Sullivan Machinery Company.**

SULLIVAN MACHINERY COMPANY. *Modern Practice in Air Compression*. 8vo. Chicago, 1907. (Catalogue No. 58.)

**U. S.—Bureau of Census.**

U. S.—BUREAU OF CENSUS. *Mortality Statistics, 1905*. 6th Annual Report. 4to. Washington, 1907.

**U. S.—Department of Education.**

U. S.—BUREAU OF EDUCATION. *Report of the Commissioner*. 1894–'95, vol. 1; 1895–'96, vol. 1–2; 1896–'97, vol. 1–2; 1897–'98, vol. 1–2; 1898–'99, vol. 1–2; 1899–1900, vol. 1–2; 1901, vol. 1–2. 8vo. Washington, 1896–1902.

**U. S.—Library of Congress.**

*Engineering Record*. Vols. 21–27, 29–40. f°. New York, 1894–'99.

*The Engineer*. Vols. 40–51, 57, 68. f°. London, 1876–'81, 1884, 1889.

*Mining Journal*. Vols. 48–52. f°. London, 1878–'82.

*Mining Magazine*. Vols. 1–3. New York, 1853–'54.

*Dingler's Polytechnisches Journal*. Vol. 197. 8vo. Stuttgart, 1870.

INSTITUTION OF CIVIL ENGINEERS. *Proceedings*. Vols. 5, 6, 10, 12. 8vo. London, 1846–'47, 1851–'53.

IRON AND STEEL INSTITUTE. *Journal*. 1891, vol. 2; 1892, vol. 1. 8vo. London, 1891–'92.



**U. S.—Library of Congress.**

WELLS, D. A. *Annual of Scientific Discovery*. 1850, 1852-'53, 1857-'62, 1864-'65, 1868-'71. 8vo. Boston, 1850-'71.

SOCIETY OF ARTS. *Journal*. Vol. 42. 8vo. London, 1894.

**U. S.—Office of the Chief of Ordnance.**

U. S.—ORDNANCE DEPARTMENT. *Report of the Tests of Metals*, 1906. 8vo. Washington, 1907.

**D. Van Nostrand Company.**

HUTCHINSON, R. W. *Long Distance Electric Power Transmission*. v, 345 p. 8vo. New York, 1907.

[SECRETARY'S NOTE.—For years there have been two "sciences" of electricity—one in the text-book, and the other in the shop and the field; and the latter has always been in advance of the former. This is inevitable in any branch of applied science, in which invention and commercial use are intensely active. But we are beginning now to get the observations and results of practice in the form of contributions to technical literature—the necessary first step toward their incorporation in scientific theory. This book is a sample of such all important additions to our knowledge, presenting a view of actual practice from the hand of a competent expert, most valuable, not only to the practitioner of to-day, but also to the historian of the future. Moreover, it contains not a little of compactly but clearly stated theory. Since long-distance electric transmission of power is never reasonably desirable, except for the utilization of a natural water-power, the book begins with three chapters, describing the laws of hydraulics, their application, and the apparatus necessary thereto. The succeeding chapters deal with electric generators, switches, and protective devices; the laws governing the transmission of energy; the transmission-line; transformers; motors; converters; practical plants; and the distinctive features of noteworthy long-distance transmission already in successful operation. The author warns his readers that his condensed discussion of some of the electric problems involved presupposes a knowledge of alternating currents and polyphase machinery. This is no drawback to the value of his work. Indeed, nothing is more exasperating to a practicing engineer than to find a new (and perhaps in many respects, an indispensable) book loaded with the re-statement of what he already possesses in other books.—R. W. R.]

**Verein Deutscher Chemiker, E. V.**

VEREIN DEUTSCHER CHEMIKER, E. V. *Mitglieder-Verzeichnis für 1907*. 8vo. Leipzig, 1907.

**F. L. Waldo.**

WALDO, F. L. *The Panama Canal*. p. 703-716 il. 8vo. n. p., 1907.

——— *The Present Status of the Panama Canal*. 16 p. il. 8vo. London, 1907.

**T. D. West.**

WEST, T. D. *Metallurgy of Cast Iron*. Ed. 11. xxiii, 638 p. 8vo. Cleveland, 1906.

[SECRETARY'S NOTE.—Mr. West, the author of this book, is a practical iron-master of long experience; and the most valuable portions of the book are those which record his own personal knowledge, gained from this experience. The circumstance that this is the eleventh edition is significant evidence of the appreciation which it has received from founders, molders, furnace-men, designers, draftsmen and patternmakers, for whose use it is specially adapted, as well as chemists, engineers, and theoretical students and investigators, who can find in it innumerable hints and observations of value. The author is specifically a foundry-man; and it is with respect to that business that he speaks with authority, though his book covers many related branches, concerning which he relies, to greater or less extent, upon the authority of others. Nobody can have thorough personal knowledge of all departments of the manufacture of iron, and it is subject for gratitude when a distinguished specialist like Mr. West, instead of holding his discoveries and experiences as trade secrets, to die with him, communicates them to his fellow-men that they may not be lost when he departs. While this work may not claim to be a complete and comprehensive theoretical treatise, it is indeed what the author, upon the title-page, declares it to be, "a practical compilation of original research" and, as such, a storehouse of facts and suggestions more valuable to both practitioners and students than many a more pretentious scientific text-book. Mr. West's theories are, perhaps, sometimes open to doubt and controversy; but his facts no practical or theoretical iron-metallurgist can afford to ignore.—R. W. R.]

## PURCHASES.

*Minerva Jahrbuch der Gelehrten Welt Herausgegeben von K. Trubner*. Year 17. 8vo. Strassburg, 1907.

*Who's Who in America*, 1906-'07. Vol. 4. 8vo. Chicago, 1907.

*Yearbook of the Scientific and Learned Societies*. Vol. 23. 8vo. London, 1906.

*Dingler's Polytechnisches Journal*. Vols. 195-201, 239-268, 279-310, 312-314. 8vo. Augsburg-Stuttgart, 1869-'99.

## MEMBERSHIP.

The following list comprises the names of those persons elected as members or associates, who accepted election during May and June, 1907:

### MEMBERS.

Alexander Anderson, . . . . .	Edinburgh, Scotland.
Rufus M. Bagg, Jr., . . . . .	Colorado Springs, Colo.
Roger L. Beals, . . . . .	Rosario, Sinaloa, Mex.
Sir Hugh Bell, . . . . .	Northallerton, England.
W. F. B. Berger, . . . . .	Leadville, Colo.
Edwin S. Berry, . . . . .	San Francisco, Cal.
Harry H. Blackburn, . . . . .	Grottoes, Va.
William D. Blackmer, . . . . .	Rhyolite, Nev.
Herman Blumenau, . . . . .	Frankfurt, Germany.
J. F. Body, . . . . .	Philadelphia, Pa.
Heinrich G. Boker, . . . . .	Remscheid, Germany.
Walter S. Brown, . . . . .	Denver, Colo.
José Campa, . . . . .	Mexico City, Mex.
Thomas Cantley, . . . . .	New Glasgow, Nova Scotia, Can.
Temple Chapman, . . . . .	Webb City, Mo.
John L. Church, . . . . .	Cobalt, Ontario, Can.
Lionel H. Cole, . . . . .	Roseland, B. C., Can.
Charles C. Crismon, . . . . .	Salt Lake City, Utah.
J. Richmond Crum, . . . . .	Mexico City, Mex.
Harle O. Cummins, . . . . .	Shasta, Cal.
Frank M. Curtis, . . . . .	Los Angeles, Cal.
Mark Daniel, . . . . .	Baker City, Ore.
Clifford G. Dennis, . . . . .	Ehrenberg, Ariz.
E. H. De Vore, . . . . .	El Paso, Tex.
Earl Dissinger, . . . . .	Canal Fulton, O.
Carl B. Dunster, . . . . .	Marquette, Mich.
Frederic Ewing, . . . . .	New Haven, Conn.
Edward F. Fitzhugh, . . . . .	Butte, Mont.
Ernest E. Ford, . . . . .	Alhambra, Cal.
Albert Frank, . . . . .	Zacatecas, Mex.
John H. Gallagher, . . . . .	Elko, Nev.
Carroll D. Galvin, . . . . .	Elko, Nev.
Frank W. Giroux, . . . . .	Mayer, Ariz.
Julius Goldberg, . . . . .	Great Falls, Mont.
William H. Hale, . . . . .	Whitcomb, Mont.
George B. Harrington, . . . . .	Elko, Nev.
Edwin F. Harris, . . . . .	Tucson, Ariz.
Paul H. Hebb, . . . . .	Tacoma, Wash.
Carl A. Heberlein, . . . . .	Torreón, Coahuila, Mex.

Stanley Hayward, . . . . .	Prescott, Ariz.
Hans L. Heldt, . . . . .	Zacatecas, Mex.
Charles L. Huston, . . . . .	Coatesville, Pa.
Paul Iweins, . . . . .	Paris, France.
Frank E. Johnesse, . . . . .	Lucile, Idaho.
Spencer Kellogg, . . . . .	Buffalo, N. Y.
Beach A. Laselle, . . . . .	Barkerville, B. C., Can.
Harold N. Laurie, . . . . .	Perdue, Ore.
William E. L'Hame, . . . . .	Covelo, Cal.
Kenneth W. McComas, . . . . .	Perth Amboy, N. J.
Benjamin E. McKechnie, . . . . .	Lebanon, Pa.
Walter F. McNeill, . . . . .	Alberta, Can.
Stewart M. Marshall, . . . . .	Johnstown, Pa.
William D. B. Motter, Jr., . . . . .	Barbara, Chihuahua, Mex.
Stephen E. Murphy, . . . . .	Mancelona, Mich.
William F. Murray, . . . . .	Denver, Colo.
Edward G. Norton, . . . . .	Edinburg, Ind.
James Lindsay Oliver, . . . . .	Chicago, Ill.
Lewis Oliver, Jr., . . . . .	Newhouse, Utah.
George A. Orrok, . . . . .	New York, N. Y.
Vance C. Osmont, . . . . .	Dayton, Nev.
William T. Oster, . . . . .	Custer, Idaho.
Sidney W. Ough, . . . . .	Guanajuato, Mex.
Francis J. Peck, . . . . .	Cleveland, Ohio.
Howard A. Poillon, . . . . .	Snowden, Cal.
Charles A. Pringle, . . . . .	San Isidro, Chihuahua, Mex.
Max Reichard, . . . . .	Saxony, Germany.
James W. Rhew, . . . . .	Sinaloa, Mex.
Fred N. Rhodes, . . . . .	Bisbee, Ariz.
Max Roesler, . . . . .	Bisbee, Ariz.
Heaton R. Robertson, . . . . .	New Haven, Conn.
James G. Ross, . . . . .	Jersey City, N. J.
Stanley C. Sears, . . . . .	Boston, Mass.
C. Quimby Schlereth, . . . . .	Durango, Mex.
Frederick W. Snow, . . . . .	Great Falls, Mont.
Charles J. Steffens, . . . . .	New York, N. Y.
Lawrence P. Stevens, . . . . .	Ironwood, Mich.
Edgar D. Stone, . . . . .	Etna, Ga.
B. Leonard Thorne, . . . . .	Hosmer, B. C., Can.
Neville F. Townsend, . . . . .	Rossland, B. C., Can.
William E. Tracy, . . . . .	Telluride, Colo.
Omar A. Turney, . . . . .	Phoenix, Ariz.
William J. Uren, . . . . .	Calumet, Mich.
Francisco B. Varela, . . . . .	Zacatecas, Mex.
Anders B. Villadsen, . . . . .	Flat River, Mo.
Edward Walker, . . . . .	London, E. C., England.
Myron B. Walker, . . . . .	Ezutlan, Oaxaca, Mex.
Russell G. Wayland, . . . . .	Treadwell, Alaska.
Frederick R. Weeks, . . . . .	New York, N. Y.
Henry P. Wherry, . . . . .	Indé, Durango, Mex.
Thomas B. Wilde, . . . . .	Nogales, Ariz.
George B. Wilson, . . . . .	Searchlight, Nev.
Clarence Woods, . . . . .	Dewey, Idaho.

### ASSOCIATES.

Max F. Abbé, . . . . .	New York, N. Y.
Paul O. Abbé, . . . . .	New York, N. Y.
William M. Hauck, . . . . .	New York, N. Y.
Lee Emmet Ives, . . . . .	Houghton, Mich.
George Sealy, . . . . .	Galveston, Tex.

### NECROLOGY.

The deaths of the following members and associates have been reported to the Secretary's office during May and June, 1907:

Date of Election.	Name.	Date of Decease.
1887.	*George B. Hanna, . . . . .	May 21, 1906.
1874.	*Frank J. Hearne, . . . . .	February 25, 1907.
1901.	†W. J. Johnston, . . . . .	April 28, 1907.
1891.	*Walter Leisenring, . . . . .	January 5, 1907.
1900.	*Robert S. Mercur, . . . . .	April 22, 1907.
1906.	**Thomas W. P. Story, . . . . .	March 15, 1907.
1878.	†John A. Walker, . . . . .	May 23, 1907.
1900.	*Eugene B. Willard, . . . . .	— — —, — — —.

\* Member.

\*\* Life Member.

† Associate.

## CANDIDATES FOR MEMBERSHIP.

The following persons have been proposed for election as members or associates of the Institute during the period, May 1 to June 30, 1907. Their names are published for the information of members and associates, from whom the Committee on Membership earnestly invites confidential communications, favorable or unfavorable, concerning these candidates. A sufficient period (varying in the discretion of the Committee, according to the residence of the candidate) will be allowed for the reception of such communications, before any action upon these names by the Committee. After the lapse of this period, the Committee will recommend action by the Council, which has the power of final election. The names of candidates were formerly published in the various circulars of the Institute, issued from time to time to the members. Hereafter, they will appear regularly in the *Bi-Monthly Bulletin*, each number of which will contain the names received since the issue of the preceding *Bulletin*.

### MEMBERS.

Lyndon K. Armstrong, . . . . .	Spokane, Wash.
Hugh C. Baker, . . . . .	Cobalt, Ontario, Can.
Astolfo Partocchini, . . . . .	Monterey, Mex.
Mowry Bates, . . . . .	New York, N. Y.
William Begg, . . . . .	El Oro, Mexico, Mex.
John L. W. Birkinbine, . . . . .	Mexico, Mex.
William Lawrence Borthwick, . . . . .	Tenabo, Lander Co., Nev.
Francis Carlton Bowman, . . . . .	Denver, Colo.
John T. Brown, Jr., . . . . .	Pittsburg, Pa.
Frederick Huntington Clark, . . . . .	New York, N. Y.
Glenville Arthur Collins, . . . . .	Seattle, Wash.
George M. Colvocoresses, . . . . .	New York, N. Y.
Frederick S. Cook, . . . . .	Joplin, Mo.
Fred Corkill, . . . . .	Tonopah, Nev.
Fritz Cremer, . . . . .	New York, N. Y.
Thomas F. Donnelly, . . . . .	El Oro, Mexico, Mex.
William F. Dutton, . . . . .	Lead, So. Dak.
Carolus D. Emmons, . . . . .	Eugene, Ore.
William H. Emmons, . . . . .	Washington, D. C.
Edward George Wickham Ferguson, . . . . .	New York, N. Y.
Charles Fowles, . . . . .	San Lucas de Campo, Durango, Mex.
Chester Alan Fulton, . . . . .	Guanajuato, Mex.

George Thomas Gambrill, Jr., . . . . .	Baltimore, Md.
Russell Tyner Gard, . . . . .	New Haven, Conn.
Lyman Francis Gordon, . . . . .	Worcester, Mass.
Boris Gorow, . . . . .	Taxco, Guerrero, Mex.
Herbert C. Hale, . . . . .	Mineral Ridge, Ohio.
Carle R. Hayward, . . . . .	Quincy, Mass.
A. Roy Heise, . . . . .	Wadsworth, Nev.
Frank L. Hess, . . . . .	Washington, D. C.
Wilson Walter Hughes, . . . . .	Ellamar, Alaska.
William S. Hutchinson, . . . . .	New York, N. Y.
Wilbur Goodspeed Laird, . . . . .	New York, N. Y.
Frederick Garrison Lasier, . . . . .	Detroit, Mich.
Charles B. Lessner, . . . . .	Carril, Spain.
Samuel Douglas McMiken, . . . . .	Auckland, New Zealand.
John Francis Manning, . . . . .	Chiksan, Korea.
J. E. Masters, . . . . .	Silver City, Idaho.
W. S. Mitchell, . . . . .	Haileybury, Ontario, Can.
Lorin Thomas Putman, . . . . .	Zeigler, Ill.
M. N. Srinivas Rao, . . . . .	Bombay, India.
Mervyn A. Rice, . . . . .	New York, N. Y.
Brent N. Rickard, . . . . .	Mapimi, Durango, Mex.
Fred Elmer Rightor, . . . . .	Clinton, Ind.
Leon Ewart Savage, . . . . .	Northport, Wash.
Oswald Norman Scott, . . . . .	Toronto, Ontario, Can.
Stewart Kedric Smith, . . . . .	Terre Haute, Ind.
Robert Walker Thomson, . . . . .	Toronto, Ontario, Can.
William H. Tolman, . . . . .	New York, N. Y.
Charles Howard Waterman, . . . . .	Aurora, Mo.
Edward Watson, . . . . .	Akmolinsk, Siberia.
Hugh Lemuel Wiley, . . . . .	Fort William, Ontario, Can.
Job Henry Winwood, . . . . .	Salt Lake City, Utah.
Charles W. Workman, . . . . .	Etzatlan, Jalisco, Mex.

#### CHANGE OF STATUS FROM ASSOCIATE TO MEMBER.

William M. Hauck, . . . . .	New York, N. Y.
Scott H. Sherman, . . . . .	Christmas, Ariz.
Benjamin F. Tillson, . . . . .	New York, N. Y.

The following changes of address of members have been received at the Secretary's office during the period of May 1 to July 1, 1907. This list, together with the list of changes of address published in *Bi-Monthly Bulletin*, No. 14, March, 1907, and No. 15, May, 1907, supplements the annual list of members corrected to Jan. 1, 1907, and brings it up to the date of July 1, 1907. The names of members who have accepted election during May and June, 1907 (new members), are printed in *italics*.

The large number of changes of address since Jan. 1, 1907, shows the importance of publishing these changes as frequently as possible, and the *Bi-Monthly Bulletin* has been selected as the means to present this information to the members of the Institute. By the simple method of cutting out these names and addresses and pasting them directly over the corresponding names in the annual list of members, the record can be kept practically up to date, and the value of the list correspondingly increased. For this purpose the changes of address have been printed only on one side of the page. The names of new members, being in italics, are readily distinguished from the others, and can be pasted in approximate alphabetical order on the margins of the pages.

Abbé, *Max F.*, Prest., Abbé Engineering Co., 220 Broadway, New York, N. Y. † '07.  
Abbé, *Paul O.*, Secy., Abbé Engineering Co., 220 Broadway, New York, N. Y. † '07.  
ALABASTER, RUPERT C., Great Australia Mine, Cloncurry, Queensland, Australia.  
ALLEN, ROBERT, The Veta Colorado Mining & Smelting Co., Parral, Chih., Mex.  
*Anderson, Alexander*, Min. Engr...27 Inverleith Row, Edinburgh, Scotland. \* '07  
ANDERSON, WILLIAM P.....Richmond and Harriet Sts., Cincinnati, Ohio.  
ARNOLD, CHARLES E. LE N.....308 W. Granite St., Butte, Montana.  
ASTLEY, JOHN W.....Care Bank of Montreal, Vancouver, B. C., Canada.  
BABB, PERCY A.....Gaute No. 12, Mexico City, Mexico.  
*Babb, Rufus M., Jr.*, Cons. Geol., 1928 N. Tejon St., Colorado Springs, Colo. \* '07.  
BAILEY, EDWARD T., Care Royal Colonial Institute,  
Northumberland Ave., London, W. C., England.  
BALDWIN, J. M.....Address wanted.  
BARD, DARSIE C., Min. Engr., Globe Mines Exploration Co.,  
Pennsylvania Bldg., Butte, Montana.  
BARKER, H. A.....Apartado 92, Pachuca, Hidalgo, Mexico.





- BAUMARTEN, KARL.....4171 Washington Ave., St. Louis, Mo.  
*Beak, Roger L.*, Min. Engr.....Minas del Taja, Rosario, Sinaloa, Mexico. \* '07.  
 BEALL, CLARENCE A..... P. O. Box 371, San Diego, Cal.  
*Bell, Sir Hugh*, Ironmaster.....Rounton Grange, Northallerton, England. \* '07.  
*Berger, W. F. B.*, Min. Engr.....Leadville, Colo. \* '07.  
*Berry, Edwin S.*, Min. Engr.....Mercantile Trust Co., San Francisco, Cal. \* '07.  
*Blackburn, Harry H.*, Min. Engr.....Grottoes, Va. \* '07.  
*Blackmer, William D.*, Min. Engr.....Rhyolite, Nev. \* '07.  
*Blakeslee, Frank A.*, Minas Tecolotes y Anexas.....Santa Barbara, Chih., Mexico.  
*Blumenau, Herman*, Min. Engr., Mgr. Central Mining Institute,  
 Mozartplatz 28, Frankfort, A. M., Germany. \* '07.  
*Body, J. F.*, Min. Engr. & Operator, 1729 Land Title Bldg., Philadelphia, Pa. \* '07.  
 BOGGS, WILLIAM R., JR.....Winston, N. C.  
 BOHN, CHARLES A.....Apartado 279, Chihuahua, Mexico.  
*Böker, Heinrich G.*, Steel Engr.,  
 Bergische Stahl Industrie, Remscheid, Germany. \* '07.  
 BOTSFORD, ROBERT S., Compania General de Minas,  
 Cruz del Eje, Buenos Ayres, Argentine Republic, So. Amer.  
 BRADLEY, RICHARD J. H.....Address wanted.  
 BRASCHI, WALTER M., Braschi & Nunez...Cadena St., No. 2, Mexico City, Mex.  
 BREEN, JAMES, Bingham Cons. M. & S. Co.,  
 Room 700, McCornick Bldg., Salt Lake City, Utah.  
 BRETT, ALFRED J., Genl. Mgr., Treasury Gold Mines, Ltd.,  
 Cleveland, Transvaal, South Africa.  
 BREWER, WM. M.....P. O. Box 701, Victoria, B. C., Canada.  
 BROOKS, ROBERT S.....Guaranty Trust Bldg., El Paso, Texas.  
 BROWN, HARVEY S.....Ruth, Nev.  
 BROWN, J. J., JR.....Troy, Ill.  
 BROWN, ROBERT G., Cons. Engr..28 St. Swithin's Lane, London, E. C., England.  
*Brown, Walter S.*, Min. Engr.....417 Boston Bldg., Denver, Colo. \* '07.  
 BROWN, WILLIAM F.....Care C. J. Ryan, 140 West 42d St., New York, N. Y.  
 BYRDEN, CHARLES L....."Cedar mont," Easton, Pa.  
 BUGBEE, EDWARD E., Asst. Prof. Min. Engr. and Met.,  
 Mass. Institute of Technology, Boston, Mass.  
 BURNAND, ALPHONSE A.....1103 Union Trust Bldg., Los Angeles, Cal.  
 BURNS, ELMER Z.....60 Wall St., New York, N. Y.  
 BUSH, B. F., Prest., Western Maryland Ry. Co., Continental Bldg., Baltimore, Md.  
 CALDWELL, WILLIAM A.....317 Onslow Drive, Dennistown, Glasgow, Scotland.  
 CALLAGHAN, JOHN T., JR.....8 Park Place, Chester, Pa.  
*Campa, José*, Engr.....5a Calle del Relox 44, Mexico City, Mexico. \* '07.  
*Cantley, Thomas*, Genl. Mgr., Nova Scotia Steel & Coal Co., Ltd.,  
 New Glasgow, Nova Scotia, Canada. \* '07.  
 CARLYLE, WILLIAM A., Cons. Min. Engr.,  
 62 London Wall, London, E. C., England.  
 CARR, HENRY C., Supt. Northern California G. M. Co.,  
 Westville, Placer Co., Cal.  
 CASE, ALBERT H., Supt., Santa Fé Gold & Copper Mining Co.,  
 San Pedro, New Mexico.  
*Chapman, Temple*, Mine Operator.....P. O. Box 314, Webb City, Mo. \* '07.  
 CHURCH, JOHN L., Min. Engr.....Prospect Hotel, Cobalt, Ont., Canada.  
 CLARK, CARLE D., Resident Mgr., Burma Mines, Ry. & Smelting Co.,  
 Mandalay, Burma, India.



CLEMENS, FRED. LE R., Min. Engr.,

Clemens & Leovitt, 206 Clay Peters Bldg., Reno, Nev.

COLE, ARTHUR A., Min. Engr.,

Temiskaming & Northern Ontario Railway Commission, Cobalt, Ont., Canada.

Cole, Lionel H., Min. Engr., Consolidated Mining & Smelting Co.,

Centre Star Mine, P. O. Box 776, Rossland, B. C., Canada. \* '07.

CRAWFORD, JOHN J.....1424 Gough St., San Francisco, Cal.

Crismon, Charles C., Assayer and Chem.....Box 78, Salt Lake City, Utah. \* '07.

Crum, J. Richmond, Min. Engr.,

Calle Colejo de Minas, No. 2, Mexico City, Mexico. \* '07.

Cummins, Harle O., Mgr., Gold Leaf Mine.....Shasta, Cal. \* '07.

CUNNINGHAM, PARKER H.....154 North Jefferson St., New Castle, Pa.

Curtis, Frank M., Min. Engr.....115 South Hill St., Los Angeles, Cal. \* '07.

Daniel, Mark, Mine Foreman.....United Elkhorn Mines, Baker City, Ore. \* '07.

DAVISON, GEORGE L., Mining Operator.....Box 521, Goldfield, Nev.

DAWBARN, GILBERT J., Min. Engr.....Moonta Mines, So. Australia.

Dennis, Clifford G., Min. Engr.,

Care Colonial Mining Co., Ehrenberg, Ariz. \* '07.

De Vore, E. H., Min. Engr. and Geol.....P. O. Box 249, El Paso, Texas. \* '07.

Dissinger, Earl, Min. Engr.....Canal Fulton, Ohio. \* '07.

DOUGLASS, ROSS E.....P. O. Box 1, Crafton, Pa.

Dunster, Carl B., Min. Engr.....Marquette, Mich. \*\* '07.

DURANT, HENRY T.....45 Nevers Square, Earls Court, London, S. W., England.

DURELL, CHARLES T., Mgr., Arcalvada Min. & Mill Co.....Cima, Cal.

EADS, NORRIS E.....Instructed to hold all mail.

EILERS, KARL.....Sea Cliff, L. I., N. Y.

ELMER, WILLIAM W.....Apartado 16, Santa Barbara, Chih., Mexico.

Ewing, Frederic, Min. Engr.....125 High St., New Haven, Conn. \* '07.

FINDLAY, JAMES.....1685 Pacific St., Vancouver, B. C., Canada.

FINK, WILLIAM N., Supt. Southwestern Nevada Mines Co.....Reville, Nev.

Fitzhugh, Edward F., Min. Engr., Mgr., Butte & Michigan Mining Co.,

25 Hirbour Bldg., Butte, Montana. \* '07.

Ford, Ernest E., Analytical Chemist.....Alhambra, Cal. \* '07.

FORD, NILE O. S.....Apartado 130, Oaxaca, Mexico.

FRANCIS, GEORGE G.....Address wanted.

FRANCIS, LEWIS W.....2 Rector St., New York, N. Y.

Frank, Albert, Min. Engr.,

Care Sombrerete Mining Co., Sombrerete, Zac., Mexico. \* '07.

FRASER, J. DIX.....New Glasgow, Nova Scotia, Canada.

Gallagher, John H., Min. Engr.....North Yam Hill, Oregon. \* '07.

Garvin, Carroll D., Min. Engr.,

Copper Basin Mining & Smelting Co., Elko, Nev. \* '07.

GAZZAM, JOSEPH P.....514 Security Bldg., St. Louis, Mo.

GEORGE, HAROLD C., Min. Engr.....Platteville, Wis.

Giroux, Frank W., Mine Supt.....Mayer, Ariz. \* '07.

Goldberg, Julius, Met. Engr.,

Boston & Montana Smelter, Great Falls, Montana. \* '07.

GRAMMAR, WILLIAM S.....Leesburg, Va.

GRIFFIN, FITZ ROY N., Peregrina Mining & Milling Co.,

Peregrina, Guanajuato, Mexico.

GUES, HARRY A.....Flat River, Mo.

HAAS, HERBERT.....27 James Flood Bldg., San Francisco, Cal.



- Hale, William H.*, Min. Engr. and Assayer.....Whitcomb, Mont. \* '07.  
*HALL, BENJAMIN M.*.....413 Temple Court, Atlanta, Ga.  
*HALL, GEORGE*.....Steephill, Gt. Beckhamsted, Herts, England.  
*Harrington, George B.*, Min. Engr.....Elko, Nev. \* '07.  
*Harris, Edward F.*, Mine Owner and Mgr., Colorado Mining Co.,  
Box 1035, Tucson, Ariz. \* '07.  
*HARRIS, HENRY*, Supt., Alaska Smelting & Refining Co.,  
Hadley, via Ketchikan, Alaska.  
*Hauck, William M.*, Mining.....223 East 87th St., New York. N. Y. † '07.  
*HAVERSTICK, JOHN E.*.....R. F. D. No. 5, Richmond, Va.  
*Hayward, Stanley*, Min. Engr.....123 S. Cortez St., Prescott, Ariz. \* '07.  
*Hebb, Paul H.*, Mining.....Tacoma, Wash. \* '07.  
*Heberlein, Carl A.*, Min. Engr. and Met.,  
Compania Metalurgica de Torreon, Apartado 93, Torreon, Coah., Mexico. \* '07.  
*HECKSCHER, LEDYARD*.....Swedeland, Montgomery Co., Pa.  
*Heldt, Hans L.*, Supt., Sombrerete Mining Co.....Sombrerete, Zac., Mexico. \* '07.  
*HELLER, MARTIN J.*.....1019 Kohl Bldg., San Francisco, Cal.  
*HILLMAN, M. P. G.*.....Trigg Furnace, Trigg Co., Ky.  
*HOFMANN, OTTOKAR*.....2110 Troost Ave., Kansas City, Mo.  
*HOLDEN, EDWIN C.*.....Room 1427, 25 Broad St., New York, N. Y.  
*HOPKINS, EDWARD*.....Address wanted.  
*HOWARD, KARL*.....1760 Pacific Ave., San Francisco, Cal.  
*HOWE, ALBION S.*.....Room 115, 339 Bush St., San Francisco, Cal.  
*HUNDSEHAGEN, LUDWIG*, Loeboe Sikaping, West Coast Sumatra,  
Dutch East Indies.  
*Huston, Charles L.*, Steel Manufacturer.....Coatesville, Pa. \* '07.  
*INGERSOL, J. W.*, Mill Supt., Topaz Mining Co., Care Brown & Harris,  
Bluefields, Nicaragua, Central America.  
*IRELAND, JAMES D.*.....Care M. A. Hanna & Co., Cleveland, Ohio.  
*Ives, Lee E.*, Student.....Michigan College of Mines, Houghton, Mich. † '07.  
*Iweins, Paul*, Civ. and Min. Engr.....48 Rue Cambon, Paris, France. \* '07.  
*JENES, ARTHUR W.*, Min. Engr. and Met.....242 Washington St., Portland, Ore.  
*JENNINGS, HENNER*, Malvern Hotel.....Bar Harbor, Me.  
*Johnesse, Frank E.*, Mine Mgr., Blue Jacket Mine.....Lucile, Idaho. \* '07.  
*JOHNSON PAUL*, Min. Engr.....Bergsingeniöven, Lund, Sweden.  
*JOST, FRED*, Min. Engr.....721 Cole St., San Francisco, Cal.  
*Kellogg, Spencer*, Prest., New York State Steel Co.,  
White Bldg., Buffalo, N. Y. \* '07.  
*KNEPPER, EARL H.*.....168 No. Los Angeles St., Los Angeles, Cal.  
*KUNZ, GEORGE F.*, Tiffany & Co.....5th Ave. and 37th St., New York, N. Y.  
*LAKENAN, CORNELIUS B.*.....Ely, Nev.  
*LANE, J. S.*.....268 Arlington Ave., Brooklyn, N. Y.  
*LA RUE, W. G.*.....208 Exchange Bldg., Duluth, Minn.  
*Lasalle, Beach A.*, Mine Owner and Mgr.....Barkerville, B. C., Canada. \* '07.  
*LASHMUTT, IVAN DE*, Testing Engr., Highland Boy Smelter,  
Utah Cons. Mining Co., Murray, Utah.  
*LAUDIG, O. O.*, Supt., Blast Furnace Dept., Penna. Steel Co.....Steelton, Pa.  
*Lawrie, Harold N.*, Min. Engr.....Perdue, Oregon. \* '07.  
*LEHMAN, GEORGE M.*, Chief Engr., Lake Erie & Ohio River Ship Canal Co.,  
1551 Frick Bldg. Annex, Pittsburg, Pa.  
*LEMPRIERE, OSCAR T.*.....64 Pitt St., Sydney, N. S. W., Australia.  
*L' Hame, William E.*, Min. Engr.....Lock Box 18, Covel, Cal. \* '07.



- LINCK, FREDK. W.....Terry's Lodge, Wrotham, Kent, England.  
 LIGHT, HERBERT H.....Instructed to hold all mail.  
*Lindsay-Oliver, James, Whitebreast Fuel Co.,*  
 1109 The Fisher Bldg., Chicago, Ill. \* '07.  
 LIPPINCOTT, WARREN B.....345 Lafayette St., Denver, Colo.  
 McCASKEY, HIRAM D., U. S. Geological Survey.....Washington, D. C.  
*McComas, Kenneth W., Chemist and Assayer,*  
 P. O. Box 174, Perth Amboy, N. J. \* '07.  
 McDEVITT, JAMES E.....1011 Mahoning Ave., Youngstown, Ohio.  
 McKECHNIE, BENJAMIN E., Min. Engr., Pennsylvania Steel Co., Lebanon, Pa. \* '07.  
*McNeill, Walter F., Vice-Prest., H. W. McNeill Co., Ltd.,*  
 Cammore, Alberta, Canada. \* '07.  
 MACKAY, ANGUS R., Min Engr.....Royal Insurance Bldg., Montreal, Canada.  
 MANN, JAMES S., Assayer, Yucca Cyanide & Milling Co.....Cedar, Ariz.  
 MANN, WILLIAM S., Care Boston & Oaxaca Mining Co.,  
 El Placer, Tlacolula, Oax., Mexico.  
 MARRIOTT, FREDERICK A., Lake View Consols.....Kalgoorlie, West Australia.  
*Marshall, Stewart McC., Asst. Engr., Cambria Steel Co.,*  
 120 Tioga St., Johnstown, Pa. \* '07.  
 MAURICE, JOSEPH, Hacienda de Monte Horcaz, por Villanueva de las Minas,  
 Provincia de Sevilla, Spain.  
 MAYNARD, REA E.....P. O. Box 132, Los Angeles, Cal.  
 MERRIAM, WALLACE W.....Apartado 145, Parral, Chih., Mexico.  
 MILLER, JAMES, Care George Miller,  
 367 Byars Road, Hillhead, Glasgow, Scotland.  
 MILLER, JESSE W.....Yale Club, 30 W. 44th St., New York, N. Y.  
 MITCHELL, DEANE P., Bewick, Moreing & Co.,  
 Equitable Bldg., Melbourne, Vic., Australia.  
 MORRISON, CHARLES E.....135 Hamilton Place, New York, N. Y.  
*Motter, Wm. D. B., Jr., Min. Engr., Mina San Diego y Anexas,*  
 Santa Barbara, Chih., Mexico. \* '07.  
 MURDOCH, JAMES V. B.....Neuck, Larbert, Sterlingshire, Scotland.  
*Murphy, Stephen E., Furnace Supt.....*Lock Box 68, Mancelona, Mich. \* '07.  
 MURPHY, THOMAS D.....1095 Avenida Chapultepec, Mexico City, Mexico.  
*Murray, William F., Min. Engr.....*1000 E. 9th Ave., Denver, Colo. \* '07.  
 NEILSON, WINTHROP C.....1111 Harrison Bldg., Philadelphia, Pa.  
 NELSON, JOHN L.....Bigbug, Yavapai Co., Ariz.  
 NICHOLSON, H. H., Min. Engr.....1506 Borland Bldg., Chicago, Ill.  
 NORTH, WHEELER O., Montgomery-Shoshone Mining Co.....Rhyolite, Nev.  
 NORTON, BEN N., Care Tomlinson & Norton, Cons. Min. and Civ. Engrs.,  
 307 Guaranty Trust Bldg., El Paso, Texas.  
*Norton, Edward G., Examiner of Mining Properties.....*Edinburg, Ind. \* '07.  
 OLDFIELD, FRANK W.....922 Equitable Bldg., Denver, Colo.  
*Oliver, Lewis, Jr., Assayer.....*Newhouse, Utah. \* '07.  
*Orrok, George A., Mech. Engr.....*New York Edison Co., New York, N.Y. \* '07.  
 OSHIMA, ROKUBO.....121 Yoyogi Toyotamagun, Tokio, Japan.  
 Osmont, Vance C., Min. Engr., Nevada Reduction Works.....Dayton, Nev. \* '07.  
*Oster, William T., Mining and Milling.....*Custer, Idaho. \* '07.  
*Ough, Sidney W., Met.....*Apartado 25, Nayal, Guanajuato, Mexico. \* '07.  
 PALMER, CHARLES S., Care J. P. Eustis Mfg. Co., 92 North St., Boston, Mass.  
 PARISH, SAMUEL F.....P. O. Box 1009, Tonopah, Nev.  
 PARKIN, WILLIAM M.....248 Fourth Ave., Pittsburg, Pa.





- PAYMAL, GEORGE W.....1621 Vallejo St., San Francisco, Cal.  
*Peck, Francis J.*, Min. Engr. and Chem.,  
 731-5 Williamson Bldg., Cleveland, Ohio. \* '07.
- PFORDE, OTTO F.....15 Donaldson Ave., Rutherford, N. J.
- PLAYTER, GEORGE H.....803 Beacon Bldg., Boston, Mass.
- Poillon, Howard A.*, Min. Eng., Supt., Lanky Bob Mine.....Snowden, Cal. \* '07.
- Pringle, Charles A.*, Min. Engr., Care Calera Mining Co.,  
 San Isidro, Chih., Mexico. \* '07.
- Reichard, Max*, Cons. Min. Engr., Stuvestrasse 32A II,  
 Dresden-Alstadt, Saxony, Germany. \* '07.
- REID, JOHN A.....Instructed to hold all mail.
- REINHOLT, OSCAR H., Genl. Supt., Arizona Diamond Drill Mining &  
 Development Co., 623 Chamber of Commerce, Los Angeles, Cal.
- RHEW, JAMES W., Mine Supt., West Coast Co.....Culican, Sinaloa, Mexico.
- Rhodes, Fred N.*, Assistant in Geological Dept.,  
 Calumet & Arizona Mining Co., Box 1459, Bisbee, Ariz. \*\* '07.
- RICE, JOHN A., Min. Engr. and Geol.,  
 The Chemung Min. Co., Tyrone, New Mexico.
- RICKARD, T. A.....667 Howard St., San Francisco, Cal.
- ROBERTS, J. C., Fuel Testing Plant.....U. S. Geol. Survey, St. Louis, Mo.
- Robertson, Heaton R.*, Assistant, Sheffield Scientific School,  
 138 Temple St., New Haven, Conn. \* '07
- ROBERTSON, HORACE P., Care R. M. Raymond, El Oro Mining & Ry. Co.,  
 El Oro, Mex., Mexico.
- ROBERTSON, P. W. K.....Apartado 48, Parral, Chih., Mexico.
- ROBINSON, SANFORD.....945 W. Jefferson St., Los Angeles, Cal.
- Roesler, Max*, Asst. Engr., Copper Queen Mines.....Box 2223, Bisbee, Ariz. \* '07.
- ROGERS, ALEXANDER P., Min. Engr.....200 W. 57th St., New York, N. Y.
- ROGERS, ALLEN H.....82 Beaver St., New York, N. Y.
- Ross, Frank A.*, Mining Supt., Mgr., Daly Reduction Co.,  
 Hedley, B. C., Canada. \* '85.
- Ross, James G.*, Min. Engr.....Hudson Cos., Pier C., Jersey City, N. J. \* '07.
- SALISBURY, EARL F.....Villaldama, Nuevo Leon, Mexico.
- SAMPLE, CLARENCE C.....5 W. 65th St., New York, N. Y.
- SANDERS, JOHN, Fernando Mining Co.....San Fernando, Durango, Mexico.
- SAVAGE, ARTHUR E., The Smelting Works...Port Kembla, N. S. W., Australia.
- Schlereth, C. Quinby*, Min. Engr.....Ojuela, Durango, Mexico. \* '07.
- SCHNEIDER, ALBERT F., Nevada Utah Mining Co.,  
 309 Dooly Block, Salt Lake City, Utah.
- SCHRADER, ERICH J.....Minneapolis Copper Co., Cumpas, Sonora, Mexico.
- SCHRAUBSTADTER, R. T.....Address wanted.
- Sealy, George*, Banker.....2424 Broadway, Galveston, Texas. + '07.
- Sears, Stanley C.*, Min. Engr.....264 Newbury St., Boston, Mass. \* '07.
- SHAPLEIGH, ROGERS W.....Fort Bayard, New Mexico.
- SHARPLEY, HAROLD, Oroya Black Range Mining Co., Sandstone, W. Australia.
- SIMONDS, FRANCIS M.....60 Wall St., New York, N. Y.
- SMITH, FRANK D. G., Santo Domingo Silver-Mining Co., Batopilas, Chih., Mex.
- SMITH, RODMAN S.....900 Boulevard, Miami, Florida.
- Snow, Frederick W.*, Min. Engr., Boston & Montana Smelter,  
 Great Falls, Montana. \* '07.
- STEBBINS, ELWYN W., Cons. Min. Engr.,  
 1201 Chronicle Bldg., San Francisco, Cal.



- Steffens, Charles J.*, Mgr., Guarantee Construction Co.,  
90 West St., New York, N. Y. \* '07.
- STEPHEN, ALFRED E.*, Assayer, Gt. Cobar Ltd.....Cobar, N. S. W., Australia.
- Stevens, Laurence P.*, Mine Mgr.....Ironwood, Mich. \* '07.
- STOCKDALE, ARTHUR H.*.....Mina Zaragoza, Zacatecas, Mexico.
- Stone, Edgar D.*, Genl. Mgr., Etna Steel & Iron Co.....Etna, Ga. \* '07.
- STRETTON, H. T.*, Care A. Thompson, Banco de Londres y Mexico,  
Mexico City, Mexico.
- STULL, JOHN W.*, Mine Supt., Allegheny Ore & Iron Co.....Lignita, Va.
- SULLY, JOHN M.*.....Silver City, New Mexico.
- SUMMERHAYES, M. W.*.....San José, Cal.
- SWAIN, SETH R.*, Min Engr.....P. O. Box 1615, Denver, Colo.
- SWEETSER, A. L.*, Min. Engr.....P. O. Box 1339, Los Angeles, Cal.
- SYMMES, OLIVER R.*.....1615 Wall St., Joplin, Mo.
- TAFT, HARRY H.*.....1470 Steele St., Denver, Colo.
- TAGGART, GEORGE K.*.....228 Reiger Ave., Dallas, Texas.
- THOMAS, T. LEWIS*.....140 North Front St., Philadelphia, Pa.
- Thorne, Leonard B.*, Min. Engr.....Hosmer, B. C., Canada. \* '07.
- TILSON, BENJAMIN F.*.....619 West 118th St., New York, N. Y.
- TOD, STUART*.....Address wanted.
- TOM, ISIDORE*, Care Simmer & Jack East, Ltd.,  
P. O. Box 47, Germiston, Transvaal, South Africa.
- TONKING, JAMES B.*.....90 West St., New York, N. Y.
- Townsend, Neville F.*, Asst. Supt., Le Roi Mine.....Rossland, B. C., Canada. \* '07.
- Tracy, William E.*, Min. Engr.....Telluride, Colo. \* '07.
- TUDOR, J. W.*.....Care H. D. Tudor, 35 Congress St., Boston, Mass.
- Turney, Omar A.*, U. S. Deputy Mineral Surveyor,  
Box 396, Phoenix, Ariz. \* '07.
- Uren, William J.*, Genl. Supt., Tamarack Mining Co., Ltd.,  
7 Second St., Calumet, Mich. \* '07.
- VALENTINE, CHARLES F.*, Cons. Min. Engr.,  
Emuford, Cairus, N. Queensland, Australia.
- Varela, Francisco R.*, Min. Engr.....Mazapil, Zacatecas, Mexico. \* '07.
- VARICLÉ, JEAN A.*.....605 Third Ave., Seattle, Wash.
- VIDLER, LOUIS W.*, 14 Colonnade Apartments,  
Colfax and Marion Sts., Denver, Colo.
- Villadsen, Anders B.*, Mill Designer, Federal Lead Co.....Flat River, Mo. \* '07.
- Walker, Edward*, Associate Editor, *Engineering and Mining Journal*,  
6 Bouverie St., Fleet St., London, E. C., England. \* '07.
- Walker, Myron R.*, Min. Engr.....Ejutla, Oaxaca, Mexico. \* '07.
- WARNER, WILLARD, JR.*, Mfr.....Chattanooga, Tenn.
- Wayland Russell G.*, Mine Surveyor.....Treadwell, Alaska. \* '07.
- WEBSTER, ERASTUS H.*.....Apartado 162, Guanacevi, Durango, Mexico.
- Weekes, Frederic R.*, Min. Engr.....36 Wall St., New York, N. Y. \* '07.
- WEPPER, G. W.*, McIntyre Hotel.....Coram, Shasta Co., Cal.
- Wherry, Henry P.*, Mill Supt., Indé Gold-Mining Co.,  
Indé, Durango, Mexico. \* '07.
- WIEL, SAMUEL C.*, Attorney-at-Law,  
823 Merchants' Exchange Bldg., San Francisco, Cal.
- Wilde, Thomas B.*, Mining.....Nogales, Ariz. \* '07.
- WILDING, JAMES, JR.*.....Apartado 1527, Mexico City, Mexico.
- WILKINSON, CHARLES*.....62 London Wall, London, E. C., England.



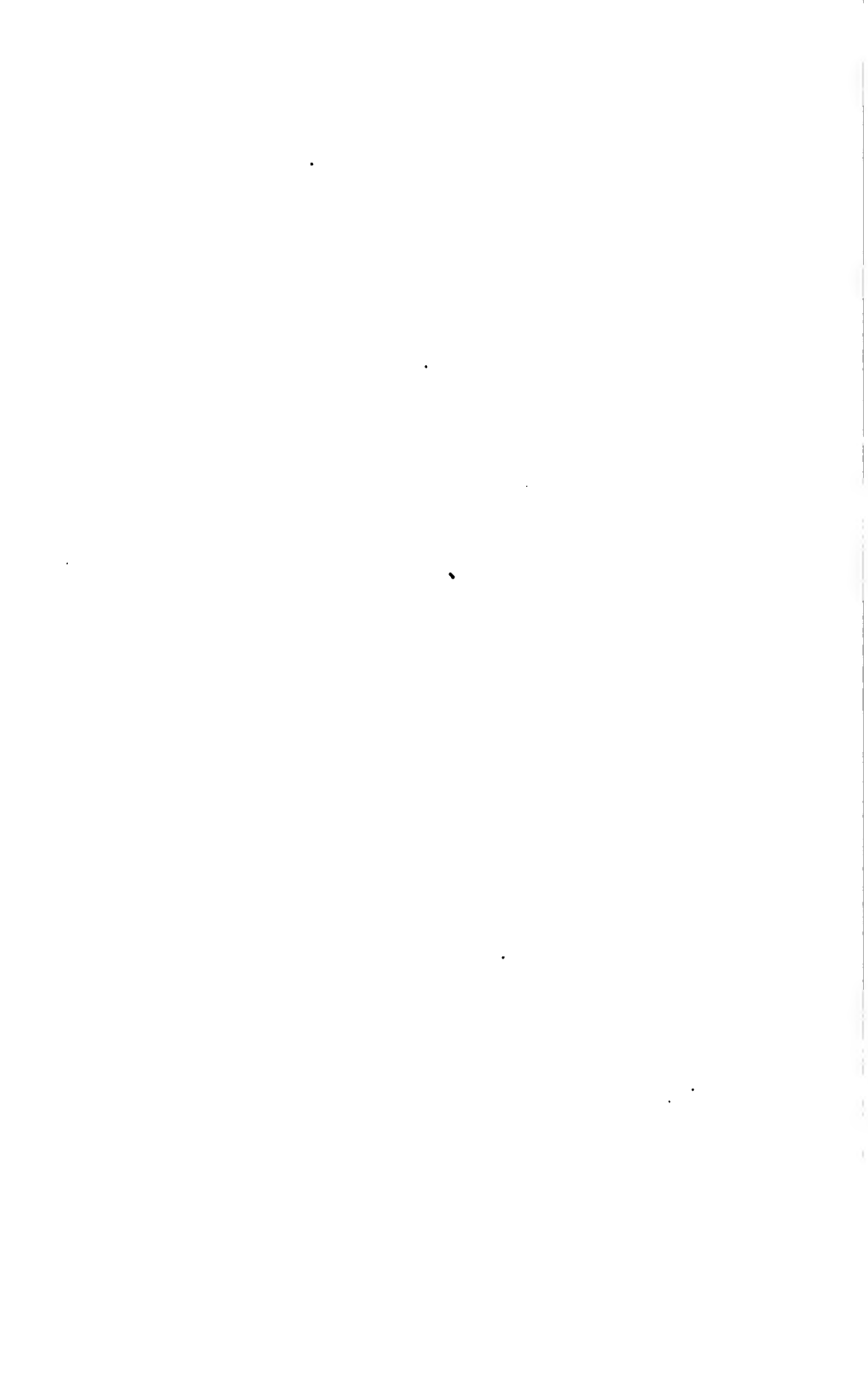
WILLIAMS, FRED. T.....	Ontaria Silver-Mining Co., Park City, Utah.
Wilson, George B., Mgr., Quartette Mining Co.....	Searchlight, Nev. * '07.
WOOD, ALEXANDER H.....	Petrog, Morgan Co., Tenn.
Woods, Clarence, Min. Engr.....	Dewey, Idaho. * '07.
WOODWARD, W. M. H.....	Placerita, Ariz.
WRIGHT, HAROLD J., New Hillgrove Proprietary Mines,	
	Hillgrove, N. S. W., Australia.
WRIGHT, LEWIS T.....	Pacific Union Club, San Francisco, Cal.
WRIGHT, WILLIAM Q., Min. and Civ. Eng., 604 Mission St., San Francisco, Cal.	
YEANDLE, WILLIAM H.....	Foreign Club, Chihuahua, Mexico.

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## ADDRESS WANTED.

Baldwin, J. M.  
Bradley, Richard J. H.  
Bruce, Thos. C.  
Burhans, Harry H.  
Doney, De Witt C.  
Ekberg, Benjamin P.  
Francis, George G.  
Hopkins, Edward.  
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## **The Influence of the Conditions of Casting on Piping and Segregation, as Shown by Means of Wax Ingots.**

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(New York Meeting, April, 1907.)

THIS paper presents an experimental verification of some of the predictions made by one of us<sup>1</sup> concerning the influence of certain conditions of casting upon the size and position of the pipe, and the position of the segregate, in steel ingots. The predictions which we have been able to verify are the following:

A. That the pipe is shortened and the segregate raised:

1. By slow casting;
2. By casting with the large end up instead of down;
3. By retarding the cooling of the top, e.g., by means of a sinking-head.

B. That the pipe is shortened by slow cooling.

C. That the pipe and segregate lie in the last freezing-part.

Our procedure was to cast ingots of wax (commercially pure stearic acid) containing a little bright green copper oleate (usually 1.5 per cent.) under varying conditions; to saw each ingot open along a longitudinal plane passing through its axis; and to examine the longitudinal section thus laid bare. In order to make the segregate or enriched part more distinct in color from the impoverished part, a very little red cerasine was added. An experiment which will be described later showed that the cerasine itself does not segregate markedly, if at all. Hence we may assume that the strong contrasts between the green and red shown in so many of our ingots are due, not to segregation of cerasine, but to that of the green oleate, in the wax which in itself is uniformly reddened with cerasine.

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<sup>1</sup> Piping and Segregation in Steel Ingots, by Henry M. Howe, *Bi-Monthly Bulletin*, No. 14, March, 1907, pp. 169 to 274.



The wax ingots themselves, shown while presenting this paper, of course have not been tampered with in any way. But the contrasts between the red and green, so beautiful in these originals, make so little showing in a direct photograph that, in order to show them in our *Transactions*, we had to paint a photographic print so as to strengthen them, and then re-photograph this print. This, in turn, is because the difference in photographic value between the green and the red is so slight.

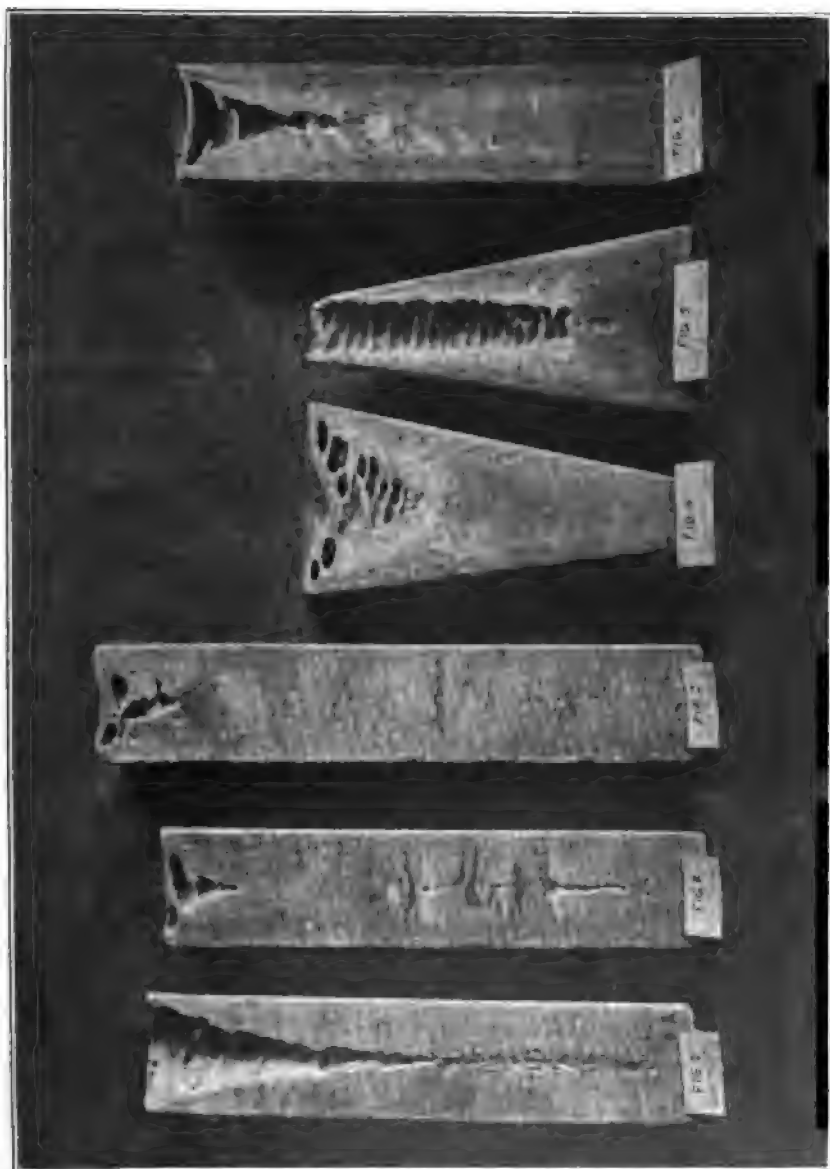
Taking up the evidence in detail, the influence of the rate of casting is shown in ingots Nos. 1, 2 and 3, Figs. 1, 2 and 3. Of these we cast Nos. 1 and 2 from the same casseroleful, half of which we transferred to a second casserole just before casting. We began the casting of these two at the same instant; but whereas the casting of No. 1 was finished in 30 seconds, that of No. 2 was so slow that, though it was continuous except for momentary interruptions for heating the wax, it lasted 1 hr. and 13 minutes.

The pipe in the fast-poured No. 1 stretches down 90 per cent. of the ingot's length, and, except for some very thin bridges, is practically continuous for 49 per cent.; whereas in the slowly-cast ingot the pipe stretches down only 14 per cent. of the length of the ingot. In this particular ingot (No. 2) there is a second rudimentary pipe near the bottom, caused by our accidentally pouring at first faster than we intended. In ingot No. 3, which was poured slowly from the start, this second pipe is absent.

The segregate in the fast-poured ingot No. 1, though not strongly marked, can be traced at A, Fig. 1, as a dark pear-shaped mass, near the bottom of the ingot. The slowly-cast ingot No. 2 has rather a succession of local axial horizontal segregates than a single segregate, as is easily understood from the extremely slow rate of casting. In the still more slowly cast ingot, No. 3, these local segregates are so slight as almost to escape notice, and there is no noticeable single segregate.

The effect of casting with the large end up instead of down is shown in Figs. 4 and 5, which represent two ingots cast in immediate succession and under otherwise like conditions from the same casseroleful.

The pipe stretches down only 30 per cent. of the ingot's length when the large end is up, but 82 per cent. when the



**Fast pouring.**

Poured fast at first,  
then slowly.

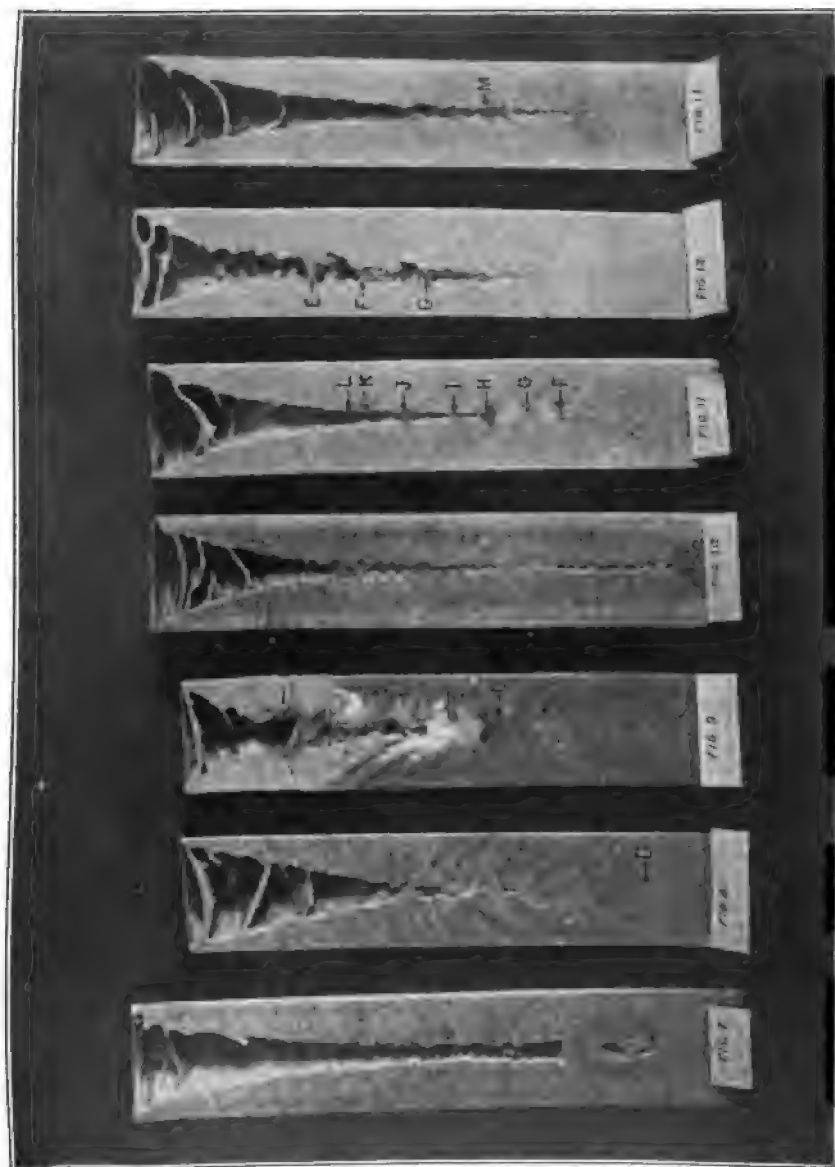
Poured very  
slowly.

Large end up.

Large end down.

Hot top, fast  
cooling.

Ingot Nos. 14  
and 15 have  
been omitted  
from the en-  
graving.



Cold top, fast  
cooling.

Cold top, slow  
cooling.

Hot top, slow  
cooling.

Warm top, fast  
cooling.

Warm top, fast  
cooling, sur-  
face-tension  
bridges.

Lateral deflec-  
tion, Cool  
warm side,  
side.

Fast cooling,  
ruined surface-  
tension bridges

large end is down, and in the latter case is a large and practically continuous cavity for 69 per cent. of the ingot's length, save for the fairy-like transparent bridges.

The segregate lies well above the center in the ingot with the large end up, but very near the bottom in that with the large end down.

The difference in size between the top and bottom of these ingots, i.e., their taper, is very much greater than in practice, with the purpose of exaggerating the effect of the direction of taper so as to make it clear to the eye.

The effect of retarding and of hastening the cooling of the top of the ingot is shown in Figs. 6 and 7, and in Figs. 8 and 9. The preparation of ingots Nos. 6 and 9 is described on p. 569.

The depth to which the pipe reaches as a nearly continuous cavity is only 26 per cent. of the ingot's length in the hot-topped ingot, No. 6, but 85 per cent. in the cold-topped, No. 7, and the extreme distance through which it can be traced is only 37 per cent. in the hot-topped against 85 per cent. in the cold-topped one. To put this in another way, if steel ingots should pipe like these, the part in which the pipe would be so oxidized that it certainly could not be welded would be only 26 per cent. in the hot-topped ingot against 85 per cent. in the other.

The segregate lies well below the middle of the pipeless part of the cold-topped ingot No. 8, but well above that of the hot-topped ingot No. 9. This pair of ingots does not show so well as Nos. 6 and 7 the influence of the distribution of temperature on the position of the pipe, because the temperature-lag of the slowly-cooling part was extremely slight, whereas in Nos. 6 and 7 it was very great. It is this temperature-lag, rather than the time-lag, that determines the depth of the pipe. The reason why retarding the cooling of the top shortens the pipe is that the upper part remains molten and thus ready to feed down into the pipe when, late in the piping-period, the inner walls are drawing outwards because of their adhesion to the virtually expanded outer walls. In order that this downward-feeding shall have a marked effect in shortening the pipe, the upper part must remain soft enough to sag thus up to the time when a large amount of the outward-drawing of the lower part shall have taken place, i.e., until the freezing of the

lower part shall have become very far advanced. But this implies that the temperature of the lower part must be much below that of the upper part, or in short that there must be a large temperature-lag.

The effect of the rate of cooling is shown in Figs. 8, 9 and 10. The pipe in the fast-cooled No. 10 runs down the axis for 91 per cent. of the ingot's length, and then branches at  $45^{\circ}$  to right and left towards the ingot's corners, following the path of the junction of the columnar crystals like that so often seen in steel ingots. In the slowly-cooled Nos. 8 and 9, the pipe stretches down 61 and 45 per cent. of the ingot's length, or in both cases very much less than in the fast-cooled ingot.

We had great difficulty in preventing this pipe-lengthening effect of rapid cooling from being masked by the pipe-shortening effect of the slower cooling of the top than of the bottom which naturally accompanies rapid freezing; and, of the two, the relative rate of cooling of the top and bottom is likely to outweigh the absolute rate of cooling, in its influence on the depth of the pipe. It was easy enough to cool the lower part of the ingot quickly, by setting the mold in iced water; but under these conditions the top lagged far behind the lower part, because from the top the heat necessarily escaped only very slowly into the air. We could not cover the ingot-top with our iced water, because that is so much heavier that it would run right down through the molten wax. Covering the ingot-top with a cold object helped us but little, because as soon as the mass began to settle an air-space formed above the wax itself, and through this air the heat passed only slowly. With ingot No. 10 we finally hit on the device of exposing it to the outer air on a very cold winter's day, with a good wind blowing. This seemed to give us about as near an approach to uniform thermal conditions at the top and bottom as could be hoped for, though the cooling of the top must still have lagged somewhat behind that of the bottom.

In slow cooling, though we saw no way of making top and bottom cool at exactly the same rate, yet we could make the difference of rate extremely small, and we could readily reverse its sign, by varying the strength of the small gas-flames played against the top and bottom of a vertical closed iron cylinder, Fig. 16, within which stood our mold, separated from the walls

of the cylinder by a wide air-space. This difference of rate between top and bottom we thus reduced so far that it no longer sufficed to mask the simultaneous pipe-shortening effect of the slow cooling itself, as is shown by comparing the pipe-lengths of the ingots Nos. 8, 9 and 10.

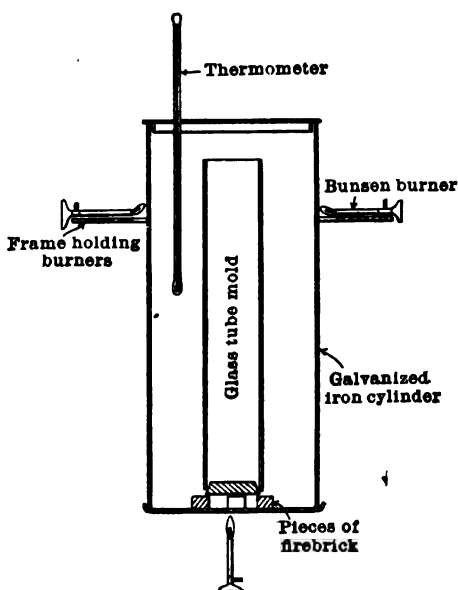


FIG. 16.—ARRANGEMENT FOR CONTROLLING THE RELATIVE RATE OF COOLING OF TOP AND BOTTOM, IN SLOW FREEZING.

Ingot No.	Rate of Cooling.		Length of Pipe, in Percentage of Length of Ingot.
	The Fastest Cooling was at	Rate of Ingots as a Whole.	
10	The bottom.	Fast.	96
8	The top.	Extremely slow.	61
9	The bottom.	Extremely slow.	45

Here the fact that the fastest cooling was at the top in No. 8 but at the bottom in No. 10 certainly tended to make the pipe deeper in No. 8 than in No. 10; nevertheless it was actually much shallower in No. 8 than in No. 10, so that the powerful effect of the change of position of the fastest cooling-point from top to bottom has here been greatly outweighed. What has outweighed it is clearly the difference in the absolute rate of cooling of

these ingots, each taken as a whole. The explanation is that the slower cooling of No. 8 has shortened its pipe to a degree which greatly outweighs the pipe-lengthening effect of its cooling faster at top than at bottom. Here, then, we verify the prediction that slow cooling tends to shorten the pipe.

Segregation is much greater in slow than in fast cooling. It is true that there is a slight concentration of the oleate in the lower part even of the fast-cooled Nos. 10 and 11, and apparently in the irregular masses which cross the pipe of the former. But the difference in tint between the red impoverished parts and the green enriched ones is incomparably greater in the slowly-cooled Nos. 8 and 9 than in the fast-cooled Nos. 10 and 11, both transversely and lengthwise. Indeed the lengthwise difference, which is very slight in the fast-cooled ingots, is so great in the slowly cooled ones that in the upper quarter of one of them, No. 9, the downward expulsion of the oleate looks complete to the eye.

That the last freezing-part contains the pipe and segregate is shown primarily in Fig. 12, and incidentally in Figs. 4 and 5, 11 and 13, and 8 and 9.

The ingot shown in Fig. 12 had its cooling hastened on its right-hand side by circulating cold water beside it, and retarded on its left-hand side by coating it with flannel, with the purpose of shifting the last freezing-part from the axis to the left. As we foresaw, this has shifted the pipe distinctly to the left of the axis.

The segregate, too, seems to have shifted so that it is concentric with the pipe. The bridges *E*, *F* and *G* are of so much darker and stronger a green than any of the rest of the ingot that we believe that they are the central axial part of the segregate; but the indications are not conclusive.

That the segregate lies in the last freezing-part is further shown by the facts (1) that it lies well above the center of the ingot No. 4 with the large end up, but far below the center in ingot No. 5 with its large end down; (2) that it lies far above the center of the pipeless part, at *C* in hot-topped ingot No. 9, but at *D* below the center of the pipeless part of cold-topped ingot No. 8; and (3) incidentally by a curious and interesting phenomenon shown in several of our ingots, but particularly well in Nos. 11 and 13. In the middle and lower part of

No. 11 there are five bridges, of which the lowest, *F*, is rudimentary, and each successive one is better and better marked as we pass upwards, until at *I* we get a distinct bridge, and at *J* one which seems to be over-ripe in a special sense. We venture to call these "surface-tension bridges," a term which we will now explain.

The pipe, as one of us has shown,<sup>2</sup> is due to the more rapid cooling and contraction of the inner than of the outer walls of the ingot in the latter part of the freezing. The down-sagging of the upper part of the mass tends to make the pipe narrower and narrower as we pass down the length of the ingot: hence the narrowing of the pipe at its lower end, and the gradual cessation of the rudimentary pipelets, for instance in Fig. 11.

The bright green of the copper oleate in this ingot shows that there are many local centers of segregation. The length of our ingots is so much greater than their width that the whole of the segregate does not usually coalesce into a single mass, but instead there are several local centers of coalescence along the axis of the ingot. Now it seems to us that each of these local segregates causes a local surface-tension bridge. That is to say, the crack which, as the beginning of the pipe, starts near the ingot's top and travels downwards along the axis, is interrupted at a point where the local enrichment of oleate has made the wax so fusible, soft, and plastic, that it stretches out like so much molasses candy under the strain, and thus forms a surface-tension bridge, instead of cracking open like the rest of the wax above and below, which, because it has less oleate, is less fusible, and therefore has progressed farther in the passage from the molten to the rigid state.

In evidence of this we point to the fact that each of these bridges from the rudimentary *F* to the over-ripe *J* is not only greener but very much greener than the wax between the bridges. Moreover, at *K*, *L* and other spots we find not bridges but promontories of like verdancy, which look as if they had passed through the stages now represented by *H*, *I* and *J*—as if they had once been bridges, but had later been torn apart by the widening and down-sagging of the pipe, and that, now left protruding as green promontories, they are really relics of former bridges.

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<sup>2</sup> *Op. cit.*, § 9 et seq., p. 180.



Like phenomena can be traced in ingots Nos. 13 and 15, though not so clearly. Had we No. 13 alone, all that we could assert would be that the very walls of the pipe in and above *M* were very much greener than any of the rest of the mass, and that the ruined bridges above also looked greener than the surrounding wax. But when we come to interpret the phenomena here and in many of the other ingots in the light of what we see so very clearly in ingot No. 11, there seems to be no reasonable doubt that these promontories and like masses are ruined surface-tension bridges.

#### SEGREGATION OR STRATIFICATION?

Without better knowledge of the relations of copper oleate and stearic acid, one might naturally ask whether we really have here a case of true segregation. May not the downward concentration of the copper oleate be only the subsidence of a mechanically suspended heavy foreign body, instead of the true segregation of a dissolved impurity? And may not the concentration of red at the top of our very slowly cooled ingots be due, not to the expulsion of the green copper oleate by segregation, as we have hitherto assumed, but to the upward concentration of the red cerasine, either by segregation or by stratification? We will now offer some evidence on these points.

To dispose first of the simple question whether the red cerasine concentrates upwards, we show ingot No. 14, made of stearic acid without copper oleate, but with the usual quantity of cerasine, and held molten for 1 hr. 50 min., to allow ample time for stratification if it does actually tend to occur, and then cooled quickly without disturbing the ingot or mold in the least, so that any stratification which should arise might persist. In spite of this ample opportunity for stratification none seems to have occurred, because the red appears to be uniform over the whole longitudinal section of the ingot. Hence we infer that the contrasts of red and green in our other ingots cannot be due to stratification of the cerasine.

Turning, now, to the question whether the concentration of the green oleate in the slowly-cooled ingots is due to stratification or to segregation, we have to admit at once that, in several of our ingots, a small quantity of copper oleate seems to have remained undissolved, and to have sunk to the bottom

of the ingot. But this applies to only a very small quantity of the oleate, and this undissolved matter is in general readily distinguished from the segregate proper, because it forms sharp grains of considerable size right against the bottom of the ingot.

Now, the mere fact that the oleate in general lies well below the center of the ingot may be explained either by the simple stratification of a heavy suspended solid, or by the greater density of the segregate due to its enrichment in the heavy copper oleate. And even the fact that in certain cases the segregate lies above the center of the ingot (the hot-topped ingots and that cast with the large end up), can readily be explained on the stratification hypothesis by supposing that the concentration by gravity was more complete in the upper than in the lower part of the ingot, because the upper part remained molten longer, giving stratification a longer time to complete itself.

But this stratification-explanation breaks down when we consider the evidence in more detail. Thus the upper parts of ingots Nos. 6 and 9 remained molten and quiescent for a very long time (1 hr. 4 min., and 1 hr. 45 min.), so that, if the impoverishment of the upper part of No. 9 was due to mere subsidence of a suspended solid, the upper part of No. 6 should have been impoverished to a comparable degree. But the impoverishment in oleate, while in the upper quarter of No. 9 it has gone so far as to approach complete expulsion, in No. 6 is very slight. The difference in impoverishment in these two cases is far too great to be explained by the stratification-hypothesis, but it is just such a difference as should result from the great difference in the rate of freezing, which was extremely rapid in No. 6, but extremely slow in No. 9.

No. 6 was cast in an iron mold standing in a large empty tub, Fig. 17. Four very gentle flames from horizontal Bunsen burners were played against the lower part of the mold, and the frame which carried these Bunsen burners was raised slowly as the tub was gradually filled with iced water, the surface of which kept pace with the Bunsen burners slightly above it. During the very slow upward travel of the water and the flame, the upper part of the ingot had over an hour in which the copper oleate, had it been mechanically suspended, would have sunk downwards; but, when any given horizontal layer of wax once began to freeze, it was rapidly frozen by the iced water.

No. 9, on the other hand, was surrounded by a hot-air jacket, as in Fig. 16, slightly hotter above than below, and the temperature of this jacket as a whole was very gradually lowered, so that there was not only a slow approach to the

freezing-range, but a very slow passage through that range, instead of the rapid passage which took place in No. 6.

As we pass inwards from the outer shell of ingot No. 6, we find first a dark band in which the freezing seems to have been so rapid as to restrain segregation very greatly. This is followed by a band in which the red predominates, and this in turn by the axial region in which the green predominates. Here we have exactly the sequence which we find in a steel ingot: an outer region but little impoverished; then a region of maximum impoverishment, followed by the axial region of maximum enrichment.

That even a true segregate should, if it is denser than the mother-mass, concentrate towards the lower part of the ingot, is only natural, as one of us has explained in case of the deep-seated segregate in ice ingots. (*Bi-Monthly Bulletin*, No. 14, March, 1907, p. 234.)

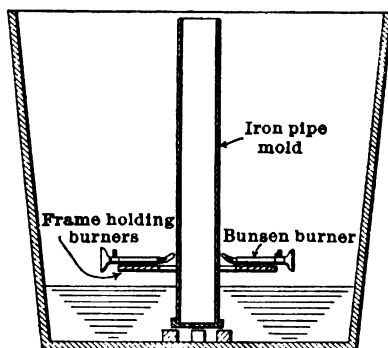


FIG. 17.—HOT-TOP CASTING ARRANGEMENT. THE FREEZING PROCEEDS FROM BELOW UPWARDS.

The green surface-tension bridges already noticed are further evidence in this same direction; and so are the diagonal streaks which we will consider later.

Though this reasoning seemed to us persuasive, we supplemented it by a direct experiment, the results of which seem absolutely irresistible. Stratification is a thing which occurs both before and during freezing, but segregation occurs only during freezing. Therefore, if we hold the mixture of wax, oleate, and cerasine molten for a very long time, longer than in any of the preceding cases, so as to afford ample time for stratification proper, and then cool it rapidly past the freezing-point so as to leave but little time for segregation; then if our phenomena are really of stratification, the upward concentration of the red and the downward concentration of the green

should be extremely strong in the resultant ingot. If, on the other hand, our phenomena are not of stratification but of segregation, then there should be only the moderate color-contrasts which the other fast-cooled ingots show.

Therefore we held ingot No. 15 molten for 1 hr. 50 min., or longer than in any of the other cases, in an iron mold within a closed air-chamber, as in Fig. 16; and then, without moving the mold itself or otherwise disturbing any stratification which might have occurred, we froze the wax rapidly by pouring cold water into the air-space which surrounded the mold. The water rose smoothly in this outer air-space, and there was nothing to disturb the wax in its mold. As may be seen, there is only the slight color contrast which the other quickly-cooled ingots show, and nothing resembling the extreme downward concentration of the green and upward concentration of the red which the slowly-frozen ingots, such as Nos. 8 and 9, show so strikingly.

The inference seems to us irresistible that the color-contrasts in these slowly-frozen ingots are due not to stratification but to true segregation. Hence it further seems that the evidence which this paper offers as to the influence of the several variables on segregation is true and valid evidence.

#### THE DIAGONAL STREAKS.

Early in this investigation we noticed curious diagonal streaks stretching inwards and upwards from the outside of certain ingots. Nos. 4, 6, 8 and 11 show these streaks in what we think nearly their natural position, and Nos. 5 and 9 show them distorted by sagging, as we will now try to explain. For brevity we will describe these in positive terms, but with the understanding that we put forth our explanation tentatively in spirit.

The red diagonal bands are the first-freezing crystals, which stretch out into the molten mother-wax. In freezing, they naturally reject part of their dissolved copper oleate, which thus concentrates in the spaces between them. They probably at first shoot out at right angles to the sides of the ingot, the cooling-surface; but from this horizontal position their inner ends swing upwards, because they are lighter than the molten wax into which they protrude, certainly because they contain less of the heavy copper oleate, and perhaps also because of the expansion of the wax in freezing. That part of the heavier

TABLE I.—*Details of Preparation and Description of the Wax Ingots.*

Ingot No.	Laboratory No.	Preparation.							Description.		
		Quantity of Cop- per Oleate.	Length.	Diameter.	Material of Mold.	Mold Surrounded By:	Rate of Cooling.	Rate of Pouring.	Depth of Pipe in Per- centage of Length of Ingot.		Depth of Center of Main Seg- regation in Percentage of Length of the Ingot.
									Total Depth.	Depth of Continuous Part.	
1	21	Per ct.	In.	In.							
2	22	1.5	9%	2	Iron.	Cold water.	Fast.	30 sec.	90 ±	49 ±	Uncertain.
3	23	1.5	9%	2	Iron.	Cold water.	Fast.	1 hr. 13 min.	14	14	66 ±
3	34	0.75	10%	2	Iron.	Cold water.	Fast.	1 hr. 39 min.	18	18	56
4	24	1.5	6%	a Large end up.	Wood.	Air.	Intermediate	50 sec.	30	30	41
5	25	1.5	6%	a Large end down.	Wood.	Air.	Intermediate	55 sec.	82	69	94
6	37	1.5	9	2	Iron.	Ice-water.	b Fast.	30 sec.	37	26	94
7	26	1.5	10%	2	Glass.	c.	Top fast, bottom slow.	40 sec.	85	85 d	85 ±
8	38	1.5	9%	2	Glass.	Hot-air jacket.	Very slow, 1 hr. 40 min.	48 sec.	61	47	86 ±
9	39	1.25	9%	2	Glass.	Hot-air jacket.	Very slow, 1 hr. 45 min.	35 sec.	45	21	59 ±
10	35	1.5	10%	2	Iron.	Air with wind.	Very fast, about ¼ hr.	25 sec.	96	33 ±	34 ±
11	15	1.5	10%	2	Iron.	Ice-water.	Very fast.	2 min 55 sec	80	45	84 ±
12	27	1.5	10%	2	Glass.	e.	(Fast on one side, slow on other side.)	40 sec.	72	30	81 ±
13	18	2.5	10%	2	Iron.	Ice-water.	Very fast.	51 sec.	81	56	62 ±
14	40	0	9%	2	Iron.	Running cold water.	Fast 1 hr.	50 sec.	53	53	.....
15	41	1.5	9%	2	Iron.	Running cold water.	Fast 1½ hrs.	55 sec.	85	37 ±	88

a Pyramidal ingots, 3½ in. square at the large end and 1 in. sq. at the small end.

b *Hot top.* The mold, which stood within a tank, was heated near its lower end by four small gas-jets, which were very slowly raised, while at the same time iced water was run into the tank just fast enough to keep its upper surface at a slight but nearly constant distance below the gas-jets. Thus the freezing at any given level was very rapid, but the freezing-zone traveled upwards very slowly. From the time the iced water rose to the bottom of the mold, till the time when it reached the top of the mold, was about 1 hr. Thus we forced the freezing to take place from below upwards.

c *Cold top.* The upper part of the mold was cooled by jacketing it with a movable coil of rubber pipe, through which cold water circulated, while the lower part was warmed by jacketing it with a fixed coil of wire heated by electric resistance. The cold jacket was lowered gradually from the top of the mold to within about 2 in. of the heating-jacket, a travel of about 6 in., in 1 hr. 15 min. Thus we forced the freezing to take place from above downwards.

d The continuous part of the pipe reaches nearly to its bottom, and extends through the thick bridge which, in the lower part of Fig. 7, masks it.

e *Lateral deflection.* The cooling of the right-hand side of the mold was hastened by jacketing it with vertical rows of rubber tubing, through which cold water circulated for 1 hr. 10 min.; and the cooling of the left side was retarded by jacketing it with flannel. Thus we shifted the last-freezing region from the axis towards the left.

molten mother-wax which is entangled or engulfed between these upward-pointing early-freezing growths, may thereby be prevented from running down to join the rest of the segregate in the lower part of the ingot; and, where opposite branches meet in the axis of the ingot, the locally-imprisoned segregate later forms one of the surface-tension bridges.

But, if there is much sagging of the mass, these upward-pointing trees are more or less bent downwards by it, and this downward bending increases with the amount of sagging. Thus there could be but little sagging in No. 4, cast with the large end up, because the freezing proceeds from below upwards; and in No. 5, with its large end down, there is very great sagging, because freezing proceeds from above downwards, as the shallow pipe in No. 4 and the deep one in No. 5 prove. It is in perfect accord with our ideas that the streaks in No. 4 point more nearly vertically upwards than in any other ingot, and that in No. 5 they are much more nearly level. In the suddenly-cooled No. 11 these streaks point strongly upwards, a natural consequence of the rapidity of cooling, which has given little time for sagging to take place; witness the great depth of the pipe. In No. 8, though the slow cooling has given plenty of time for sagging, there has actually been but little because of the cold top, which has led to a deep pipe; and it is quite in accord with this that the streaks point strongly upwards in spite of the slow cooling.

Finally, in the slowly-cooled hot-topped No. 9, both the slow cooling and the fact that the upper part remained molten and free to feed down into the pipe, led to so much sagging as both to cause a short pipe and to overturn these initially upward-pointing trees, and make them point downwards. In this case the sagging was so extreme that the ingot shortened itself by about 5 per cent. Thus in every respect the position of these streaks agrees with our explanation of their nature.

We have to thank Dr. Parker C. McIlhiney most warmly for aid in choosing these substances, copper oleate and cerasine, for showing these effects of segregation; and Mr. E. C. Groesbeck, S.B., for his careful and efficient execution of most of the manipulation.



## Notes on the Gayley Dry-Air Blast-Process.

A Discussion of the Paper of C. A. Meissner, presented at the Bethlehem Meeting, February, 1906, and printed in *Bi-Monthly Bulletin*, No. 9, May, 1906, pp. 385 to 399.

(New York Meeting, April, 1907.)

J. E. JOHNSON, JR., Glen Wilton, Va. (communication to the Secretary\*):—Mr. Meissner announces early in his paper that one of its purposes is the discussion of my paper entitled, *Notes on the Physical Action of the Blast-Furnace*,<sup>1</sup> with which he disagrees in part; and as the second stage of the discussion of this important subject has centered around his paper, some reply by me may not be amiss.

Unfortunately, Mr. Meissner has not indicated a single statement or conclusion in my paper that he wishes to controvert; but as there is evidently a difference of opinion between us I will disregard this fact, and will discuss those conclusions of his that seem to me not to be justified by the facts of general practice, or even by the data which he produces to support them.

Let me say, however, that I am a believer in the dry-air blast; in fact, a more consistent one, apparently, than Mr. Meissner, since to me the great advantage of the dry-air blast appears to be its dryness. In my opinion, it is not necessary to produce factitious explanations for the success of this great improvement.

Mr. Meissner's first contention is that natural-air blast has not shown the increase in output and the decrease in fuel-consumption when the air is cold and dry in winter, which was caused by cold, dry blast artificially produced. He cites, in support of his contention, the records of 90 furnaces, extending over a period of from four to six years, which failed to show these results.

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\* Received July 3, 1906, too late to be printed for the London meeting; subsequently revised in minor details by the author, and returned for publication Nov. 19, 1906.

<sup>1</sup> *Trans.*, xxxvi., 454 to 488.



I shall deal presently with the explanation of this fact, but first I wish to say that this contention is opposed to the experience of almost every practical furnace-man of my acquaintance, excepting some of those using Lake Superior ores.

Mr. Gayley himself, in the specification for his original patent on drying the blast by refrigeration, says: "Thus in the summer months, because of the greater content of moisture in the air, 200 lb. more fuel on an average are required to produce a ton of pig-iron than in the winter months." Mr. Gayley was at that time managing the largest blast-furnace plant in the world; and better testimony on such a subject it is impossible to imagine.

About 8 or 9 years ago I took the records of fuel-consumption and output of a furnace in Virginia for three years, week by week, taking the average for corresponding weeks, and omitting from the record those weeks in which the furnace was shut down for repairs. The furnace was run during the entire period on the one kind of ore, with a uniform blast-temperature (850° F.), and made the one kind of iron (basic). In order not to show the absolute coke-consumption, and to show the variations more plainly, the quantity in excess of a certain fixed amount was plotted, as shown in Fig. 1. The results hold good to the present time; that is, the same annual variations of fuel-consumption and output occur, except as they may be masked by periods of better or worse working, which, unfortunately, are generally beyond the furnace-man's control. Throughout the South, wherever close attention is paid to fuel-consumption, the same results hold to a greater or less degree, as far as my experience extends, and that also of others with whom I have discussed the subject. In fact, this condition has so long been one of the banes of furnace-men's existence that further discussion of the point is hardly needed. The effects are more definitely measurable in the case illustrated by Fig. 1 than in most others, for the reason that the percentage of variation in available heat caused by a given amount of moisture is much greater with a low blast-temperature than with a high one. For instance, from the diagrams published in my paper above referred to, the available heat with 0.25 lb. of moisture and 1,250° of blast-temperature is 1,910 B.t.u.; for 1 lb. of moisture at the same blast temperature, it is 1,650 B.t.u., a re-

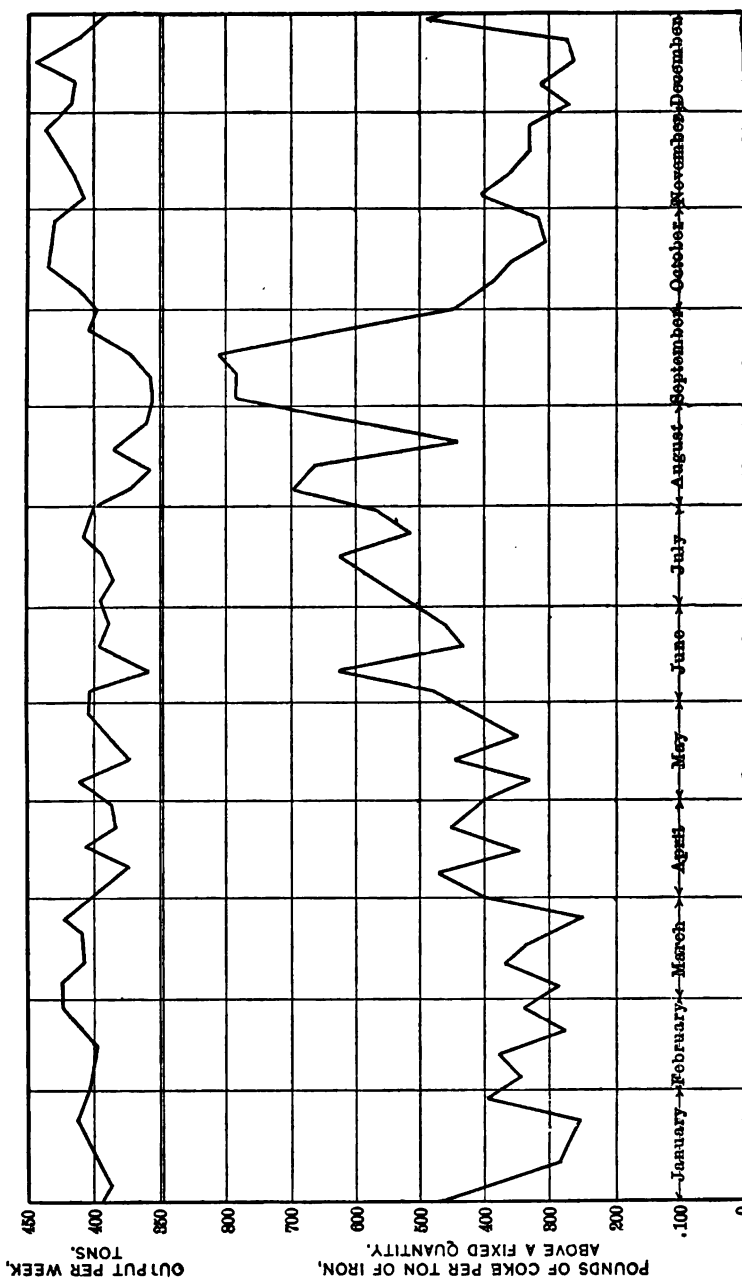


FIG. 1.—WEEKLY AVERAGE OF COKE-CONSUMPTION AND OUTPUT FOR THREE YEARS OF A VIRGINIA BLAST-FURNACE.

duction of 14 per cent.; for  $750^{\circ}$  blast-temperature, with the same amount of moisture, the available heats are 1,300 and 1,045 B.t.u., a reduction of 20 per cent., or about 45 per cent. more than in the previous case.

In this connection another point is to be borne in mind. When the furnace is carrying a good burden the gas is lean, and of relatively small quantity; consequently there is relatively little left for heating the stoves, after the boilers have been supplied, and the blast-temperature is, therefore, comparatively low. When, on the other hand, the burden is low, the gas is abundant and rich, and there is consequently a larger supply for the stoves and the blast-temperature can be suitably raised. The result is that the work of the furnace tends to be equalized throughout the year; that is to say, when the furnace might be able to carry a good burden, it can only go as far in that direction as the reduction of blast-temperature (due to the impoverishment of the gas) will permit. If, on the other hand, the furnace tends to work badly, the increased heat in the blast obtainable from the enrichment of the gas tends strongly to correct this condition.

In the furnace, the operation of which is shown by Fig. 1, this was not the case, since it was equipped with iron-pipe stoves, on which the maximum permissible temperature was  $850^{\circ}$ ; and this was always maintained, even though firing the boilers with coal became necessary in consequence of a deficient gas-supply.

This reasoning does not fully apply to the 90 furnaces of which Mr. Meissner speaks, because many of them do not use all the heat that their stoves would permit, for reasons well known to furnace-men—namely, (1) the liability to make the furnace “stick,” and (2) the desire to have in reserve enough heat to help the furnace through a sudden “spell.” But in this case a new factor becomes operative; this is, that the furnace-man, who fears to stick his furnace with too high a blast-temperature, will always use all the heat that the furnace seems willing to take. Consequently, when the summer months come and the humidity rises, thus producing a chilling action in the hearth, these furnace-men naturally will order the stove-tender to carry a higher blast-temperature, because they see that the furnace will stand it.

These considerations explain to a very great extent, if not wholly, the reason why furnaces, especially those using Lake Superior ores, with their liability to stick, do not show the difference in fuel-consumption between summer and winter conditions which might be expected. Add to this the fear of every furnace-man that his furnace will be caught by a slip, or a dose of water, or a violent change in the humidity, at a time when it is already carrying all the burden under which it can stagger, and his desire to have a reserve with which to meet this possible change, and the conditions described by Mr. Meissner are completely explained.

It is perfectly well known to most furnace-men that a furnace will work more regularly, with less liability to slips and other derangements, on a heavy burden than on a light one. Therefore, when the furnace-man feels himself secure against atmospheric changes, he is justified on that account in carrying all the burden he can (as we have Mr. Gayley's own word that he did). The effect of this increase of burden is to further steady the furnace, and reduce the irregularities other than those caused by variations in the humidity. This makes the effect of the dry-blast cumulative in two or three directions.

In this connection, it may be well to state that owing to regularity of work at the Virginia furnace, the records of which are graphically shown above, it was the custom to put on all the burden that the furnace could carry, the danger from slips and other accidental derangements being a minimum.

It has been generally declared that the diurnal variations of the humidity are very great, and that the removal of these variations is in itself a great advantage, but I confess that both the facts and the results seem to me to oppose this view. There is a diurnal variation in the humidity, and on some occasions it is rapid and of great extent; but these occasions are comparatively rare in most seasons; and many years of patient but unsuccessful endeavor to make the facts fit the theory, and to prove that a furnace works better at night than during daytime in summer, have convinced me that the diurnal variations are, under ordinary circumstances, no more than a furnace in good condition can meet with its reserve of heat, without showing ill-effects.

On pages 4 and 5 of his paper, Mr. Meissner has made some

comparison of actual results with those indicated by my diagrams. Unfortunately, a serious typographical error has occurred, for which Mr. Meissner is not responsible, but the effect of which is lamentable, as it tends to throw complete discredit on the diagram. The entire sentence is as follows: "According to Mr. Johnson's diagram, this increase from 850° F. to 1,200° F., on a blast containing 2 grains of moisture per cu. ft., should increase the 'available heat' from 1,450 to about 1,850 B.t.u. Theoretically, this would reduce the coke-consumption of 1,875 lb. for the former temperature, to about 1,270 lb. for the latter." The words "about 1,270 lb." should be "about 1,470 lb.," a result which is, of course, very low, but not so far from the very best practice as to be ridiculous.

Through the kindness of Mr. David Baker, I obtained a brief statement of the work of No. 6 furnace, at South Chicago, for 1897, which shows an average fuel-consumption of 1,580 lb., with a blast-temperature of 1,130°. Considering that this covers the entire year and that the average humidity was, therefore, not far from 0.5 lb. of moisture per 1,000 cu. ft. of air during the entire time, the available heat for this case by my diagram is about 1,690 B.t.u. This corresponds, on the basis given by Mr. Meissner, to 1,620 lb. of fuel, more than was actually used, so that if the blast were dry and the temperature raised to 1,200°, it is not unreasonable to suppose that on a similar ore-mixture a fuel-consumption of very nearly 1,470 lb. could be reached, as the diagram indicates. An additional confirmation of these figures is to be found in the actual work of the Dover furnace, under the management of Mr. Arnold K. Reese, as described by him,<sup>2</sup> in which the fuel-consumption was about 1,660 lb. and the blast-temperature about 1,150°. I think it may be claimed, therefore, that the results taken from my diagram show as close an agreement with the actual results of blast-furnace operation as would be expected by those who have had actual experience with that uncertain apparatus. Mr. Meissner's own figures prove this clearly for the lower blast-temperatures, and, when properly corrected, prove it as well as can be expected for the higher ones, also.

*Mr. Meissner's Argument for Perfect Uniformity.*—The second portion of Mr. Meissner's argument is devoted to proving that

<sup>2</sup> *Trans.*, xxvii., 477 to 485.

the advantage of the dry-blast lies principally, not in its dryness, but in its uniform density and content of oxygen. On this latter subject, much has been said by European metallurgists; and it seems worth while to point out that the variation in oxygen-content of air with the amount of moisture present is not rapid, and that it actually increases as the moisture increases after a certain point is reached. To show this, I have reproduced in Table I. Mr. Meissner's Table II., and have extended it to 112° F., and have added on the right a column showing the oxygen in pounds per cubic foot of saturated air at the different temperatures.

TABLE I.—*C. A. Meissner's Table II., with Oxygen per Cubic Foot of Saturated Air Added.*

Difference in Saturated and Dry Air per cubic foot at different temperatures.

Grains of Moisture at 100 Per Cent. Saturation.	At	Saturated.	Dry	Oxygen per cu. ft. Pounds.
0.55	0° F.	equals 0.0863 lb. per cu. ft. of air, or	0.0864	0.01990
0.91	12° F.	equals 0.0841 lb. per cu. ft. of air, or	0.0842	0.01943
2.12	32° F.	equals 0.0805 lb. per cu. ft. of air, or	0.0807	0.01870
4.38	52° F.	equals 0.0772 lb. per cu. ft. of air, or	0.0776	0.01819
8.54	72° F.	equals 0.0739 lb. per cu. ft. of air, or	0.0747	0.01780
15.75	92° F.	equals 0.0707 lb. per cu. ft. of air, or	0.0720	0.01772
27.68	112° F.	equals 0.0631 lb. per cu. ft. of air, or	0.0694	0.01800

It will be seen that this reaches a minimum about 95° F., and thereafter increases, for the reason that air contains only 25 per cent., by weight, of oxygen, while water-vapor contains 89 per cent. It may be objected that the oxygen is combined with hydrogen, and therefore does not count; but this fact does not interfere in the least with its combination with the fuel to form CO, and the hydrogen released at the same time is a desirable reducing agent, so that if the question of heat be ignored, as it has been by so many in this discussion, the blast-furnace should really work better with saturated air above 100° than it does with dry-air at lower temperatures. No one has actually claimed this, but it is a not altogether unreasonable deduction from the arguments of many.

Referring to Mr. Meissner's attempt to trace the results obtained to uniformity of temperature of the dry-blast, on pages 8 *et seq.*, I think that they may all be dismissed with the verdict "Not proven." The variations in the humidity as shown

by Mr. Meissner's comparative tables are, it is true, greater than the variations in temperature of the dry-blast; but while the relative variation of humidity is considerable, the absolute variations are negligible from a metallurgical point of view. The diagrams given in my paper show a greater variation in probable fuel-consumption for a given variation in moisture, by from three to five times, than any other method of calculating this loss; therefore, if the variation in humidity shown by Mr. Meissner's tables were of importance, this would be shown by the corresponding variation in available heat as taken from my diagram. The extreme variation in moisture given in Table V., with the exception of one month, is 1.25 grains, which would correspond to a variation in available heat of about 60 B.t.u. out of a total of 1,500 B.t.u., or about 4 per cent. On any other basis of calculation than mine the variation would be less than 1 per cent. To claim that the superior work of one period over another was due to any further reduction in this small quantity is utterly inadmissible; in fact, Mr. Meissner himself gives the clew to better work of No. 3 furnace, than of No. 1 on dry-blast, when he speaks of the "troubles at the furnace due to accidents and repairs and to leakage of bosh-plates." To attempt to compare the work of two furnaces, of which one had these troubles and the other was free from them, in order to evaluate a gain in uniformity of dry-blast temperature, is hardly less than preposterous. In fact, the differences as between variations of humidity and variations in dry-blast temperature given by Mr. Meissner's table are so utterly insignificant in comparison with the variations of furnace-work under the most uniform and favorable conditions that any inferences so drawn are of no more value than an attempt to determine the distance of the Pole Star by taking its parallax from opposite ends of a two-foot rule. Above all, to give these comparisons without giving in detail the variations in hot-blast temperature which accompanied them, and which are almost certain, in some cases, to have been of many times greater moment, is utterly useless.

On page 14, Mr. Meissner claims that the calculated effect of higher blast-temperature upon fuel-economy is not realized in general practice. From this statement I am forced to dissent. So far as known to me, there has seldom been a blast-furnace run remarkable for low fuel-consumption under given

circumstances without a high blast-temperature; and while a high blast-temperature may not always give a low fuel-consumption, as compared with practice on Lake ores, high blast-temperature and furnace-management has, in almost all cases, given a lower fuel-consumption than a lower blast-temperature under the same conditions. The exception to this statement is the one with which Mr. Meissner is familiar—namely, that of Lake ore practice, where limitations caused by liability to stick and bad furnace-work prevent obtaining from high blast-temperature those benefits which are almost universal under other conditions.

Mr. Meissner says that an increase of  $300^{\circ}$  in blast-temperature would probably not result in a decreased fuel-consumption of 400 lb. per ton of iron, and that practice indicates 50 lb. of fuel saved per  $100^{\circ}$  increase in blast-temperature. I have dealt with this probability in the early part of this discussion; but it may be well to point out again the fact on which special emphasis was laid in my paper—namely, that the fuel-economy of the blast-furnace is subject to a double limitation: first, that arising from the total amount of heat generated per pound of iron produced; and second, that arising from the fact that a sufficient portion of this heat may not be available above the critical temperature to complete the smelting-process. One of these depends, roughly speaking, on the degree of oxidation of the carbon in the waste gases; the other depends upon the temperature and the dryness of the hot-blast. These two limitations are practically quite independent of one another; and whichever of them comes into action first will limit the economy of the furnace, even though the other still have an ample margin. This is a theorem which I believe to be absolutely essential to the proper understanding of the operation of the blast-furnace. Without it, many unwarranted conclusions will be drawn, and many points will fail to be understood. Its bearing on the present matter is, that if, in a given furnace, the top gases are already oxidized to the maximum possible extent for the given conditions, further increase in the temperature of the blast will have practically no effect. If, on the other hand, the gases are much less oxidized than is possible under the given conditions, then increase in blast-temperature will be followed by economy of fuel, in all those cases in which the increase in



temperature does not occasion a tendency to stick and consequent irregularities. The conditions controlling this last occurrence need not be discussed at length here, and are hardly germane to the present discussion.

As to the reduction in the power required, there is no doubt that this is a factor worthy of consideration, but one of the reasons for it has been entirely overlooked. This is, that the furnace requires less blast to burn the smaller quantity of coke charged, and as the pressure to drive the blast through the furnace varies nearly as the square of the volume used, the pressure on the furnace falls materially, and therefore the work of the blowing-engine is very considerably reduced, altogether apart from the saving made by the reduction in the volume of the air, due to its lower temperature at entrance into the blowing-cylinders. That this saving also exists is not to be denied; but considered by itself, it would be a very expensive one at the price paid for it—namely, the power required to refrigerate the blast.

In the discussion by Prof. Richards on this subject at the Washington meeting, May, 1905, and at the Bethlehem meeting, February, 1906, he has failed to grasp the importance of the conception of a critical temperature, and of the double limitation to fuel-economy just mentioned. As a consequence, his analysis, while interesting, does not advance our knowledge of the subject; since he attempts to evaluate causes to which it is not possible to attach exact values, and the introduction of which is unnecessary to account for the results achieved. Prof. Richards's heat-balance, in his paper of May, 1905, has its greatest interest in showing, with a little additional calculation, a fact which he ignored—namely, that the total quantities of heat actually used in the furnace per pound of iron made were identical (within the limits of such calculations) with and without the dry-blast, thereby disproving the very foundation of many arguments concerning this process.

To Prof. Howe I am under lasting obligation for having restated with his faultless clearness of expression the views set forth in my paper, and for having illustrated them at such length, and with such clearness as to render their acceptance much more certain and more rapid. I think, however, the fact has been generally overlooked that in my paper I not only

called attention to the existence of a critical temperature and to its importance, but also was at some pains to determine what this critical temperature was, an effort in which I expended more than a year. It should not, therefore, be thought that the existence of a critical temperature depends upon mathematical demonstration or that it may be fixed by mathematical analysis, because, if my views are correct, the critical temperature is a metallurgical fact which is determined within a comparatively narrow range by the circumstances of any given case.

In conclusion, it is probably safe to repeat that the great advantage of the dry-blast is its dryness, and that that portion of its results which cannot be explained directly on that account alone is completely accounted for by the moral and material secondary advantages which come from it, as explained above.

C. A. MEISSNER, New York, N. Y.\*:—I have listened to the reading of Mr. Johnson's paper very carefully, and I can so far only say that I have nothing whatever to change in the notes that I made at the time. I think that a careful study and analysis of the wording and meaning of what I then said will practically answer most if not all of Mr. Johnson's contentions. I have given in that paper purely a statement of facts; I have not theorized, but have given the facts as I found them after more than two years' study of both dry-blast and normal blast, and to go into any detailed discussion of Mr. Johnson's paper would only be taking up your time, because, as I say, I cannot change any of the facts I have presented. I think the deductions that the facts have shown are good. I have gone over them again recently and I have nothing whatever to change in them at this time.

HENRY M. HOWE, New York, N. Y.\*:—To say that the reason why dry-blast causes the remarkable fuel-saving which has been shown is that it leads to regularity, seems to me absolutely no explanation at all, because it leaves us wholly in the dark as to why regularity should cause so great a saving of fuel. It simply pushes the question one step further off, throw-

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\* Oral discussion at the New York Meeting, April, 1907.

ing absolutely no light on the question of the true cause of the saving of fuel.

On the other hand, the explanation that the dry-blast widens the margin between the temperature developed and the critical temperature of the blast-furnace operation, as put forth by Mr. J. E. Johnson, explains the saving readily, clearly and convincingly, at least if we couple with it the necessary amendment which I have offered.\*

MR. JOHNSON :—I wish to say that, contrary to Mr. Meissner's impression, I did study his paper and conclusions very carefully before I wrote my own. It is only fair to say that he had the facts, whereas I had only the observation of allied facts, and I was exceedingly careful to give due weight to that evidence; but the result of all my thought on the subject is to confirm my original conclusion in view of the very strong case Mr. Meissner has prepared, and in my paper those interested will find a reason why there is a lack of variation between dry-blast and normal blast in the summer- and winter-conditions in the Pittsburg region, which is too technical to go into here.

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\* *Iron, Steel and Other Alloys*, by H. M. Howe, 2d edition, pp. 457 to 475.

## **The Vein-System of the Standard Mine, Bodie, Cal.**

BY R. GILMAN BROWN, LONDON, ENGLAND.

(New York Meeting, April, 1907.)

### **INTRODUCTION.**

MINES are interesting by reason of what they have done for man, or of what has been done for them by nature. Not all are interesting on both scores. Many profitable mines are commonplace to the geologist; and many presenting unique geological conditions have been sad failures commercially.

The Standard group at Bodie has produced in 25 years, \$14,500,000, paying \$5,000,000 in dividends.<sup>1</sup> On the other hand, this output has been mined (almost wholly above the 1,000-ft. level) from a system of more than 100 veins, ranging in thickness from 0.5 in. of "specimen rock" to 30 ft. of clay and quartz; distributed through a zone about 2,000 ft. in width, and representing from three to five distinct periods of formation. This group, therefore, by reason of its industrial record as well as its geological features, may fairly be regarded as doubly interesting.

The Bodie district occupies an island of recent (Tertiary) hornblende-andesite, surrounded by a complex of igneous rocks and breccias. It lies at the summit of the eastern foot-hills of the Sierra Nevada mountains, and within the Great Basin, a few miles from its western edge, marked here by Mono lake on the line of the Great Fault. The average elevation of the outcroppings of the veins may be taken at about 8,700 ft. The andesite projects from south to north in a great tongue, 12,000 ft. long and 5,000 ft. wide, reaching an extreme height at the northern end of perhaps 1,000 ft. above the adjoining small canyons. These separate it from the main mass of the foot-hill

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<sup>1</sup> Regular mining began practically in 1879. Down to 1884, the gross product was \$7,662,000, and the dividends amounted to \$3,525,000. For the 10 years, including 1894, the record was: gross product, \$1,996,000; dividends, \$186,000; and for the next ten years, gross product, \$3,101,000; dividends, \$449,000.

complex on the west, the north and the east, but the south end of the tongue is rooted into the complex. Surface indications point to a structural line of separation, very probably a line of fault, at the point of union. At the very heart of this andesite mass lies the Standard group of mines, the richest and most productive of the district. The original Standard mine consisted of but two claims; but during the past 10 years it has come to include the properties formerly known as the Bodie, Mono and Lent Shaft, on the south; the Bulwer and Belvidere, on the west; the Bodie Tunnel and Tioga, on the north; and the Summit and Harrington Tunnel on the east—in all about 200 acres. Portions of the surface are covered with large blocks of flinty quartz, of low value; there is also much debris, characterized by large feldspar (albite) crystals. I have observed a single straight face on one of these crystals 4 in. long. This remarkable occurrence is found as well in the upper workings, where the well-defined albite crystals are associated with quartz, and, in more than one specimen, the crystals are mere shells, studded internally with fine prisms of quartz. I have never identified gold in association with the feldspar, but have many times panned out gold from specimens of mixed quartz and feldspar. My impression is that the gold occurs only in the quartz. Some features point to the albite as a secondary constituent of the veins. But it cannot easily be identified deep in the mine, and the matter has not received much study, so that no definite conclusions have been reached concerning it.

In the main, the soil is thin; but along two lines of depression crossing the property, there is a heavy covering of what is locally known as blue clay. These zones, mentioned later in this paper, are probably due to surface decomposition of the andesite along lines of shattering. The surface is devoid of trees; but it is interesting to note that a section of silicified wood, part of the trunk of a tree that must have been 14 in. in diameter, was found in the wash below the Bulwer shaft.

#### THE VEIN-SYSTEM.

This is made up of at least three series: in the order of their age, the Fortuna, the Incline and the Burgess; in the order of their yield, the Incline, the Fortuna and the Burgess.

Fig. 1 is a generalized sketch in cross-section of these series with their modifying dikes and faults. The oldest series, the Fortuna, is dislocated by each of the succeeding ones, so that its veins are cut up into short segments. The resulting complexity is increased by the divergence of strike, which makes of each disjointed vein-segment a polygon that is far from a parallelogram. The other two systems are, in the main, on the hanging-wall and foot-wall sides, respectively, of a

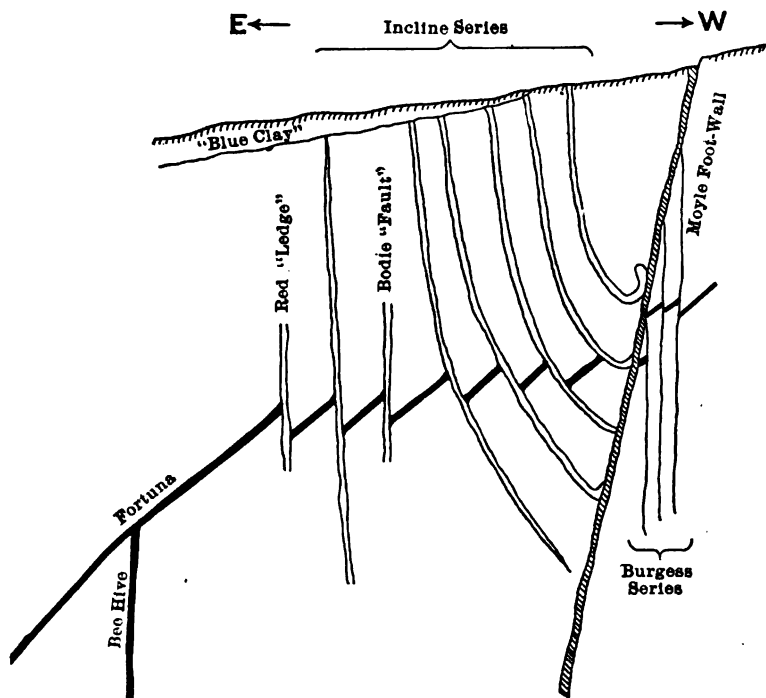


FIG. 1.—CROSS-SECTION OF THE VEIN-SYSTEM OF THE STANDARD MINE.

strong line of fault—the Moyle “foot-wall”—which cuts boldly through the mines. A few unimportant members of the Incline series are found to the west of this fault, but none of the Burgess veins are found to the east of it, unless, as is only barely possible, the enriching-veins, of which mention is made later, belong to this series. In addition, there are at least two dikes faulting the Fortuna, the Red Ledge and the Bodie “fault.” Between these and the Incline series, no intersections have been developed which would determine their rela-

tive age. They are several hundred feet from the Burgess series, and probably do not cut any of its members.

The ore of the Fortuna is characterized by hard, flinty, at times bluish, quartz, "frozen" on to the walls. The bullion produced has the largest percentage of silver of any of the series; the visible gold being noticeably light in color. The Incline series shows a relatively small proportion of coarse gold and stands lowest in silver percentage; and the Burgess is characterized by exceedingly coarse gold, 50 per cent. of which will stay in the mortars by its mere weight, without the aid of inside amalgamation. In both the Incline and the Burgess series, the quartz is well banded and sharply separated from the walls.

We have thus three sets of veins occurring in close juxtaposition in the same country-rock, and at times intersecting one another, yet each with a marked peculiarity of gold occurrence, and each so distinct in the appearance of its quartz that hand-specimens can be recognized with ease. Added to this is the diversity of dip and strike, making it as difficult to ascribe the fissuring in all cases to the same set of forces, as the gold to the same source.

#### *The Fortuna Series.*

The general characteristic of this series is a strong fissure, at times accompanied by andesitic breccia, on one or the other wall, or partly silicified in the vein, as if the mineralization had followed the line of an earlier dike. This, however, is not completely demonstrated; nor is the breccia by any means a constant feature. Only two veins of this series have been productive (though a third, unimportant one exists)—namely, the Fortuna and the Beehive, which yielded the richest ore of the old Bodie mine. The later vein-series and dikes have all "had their fling" at the Fortuna; and the consequent dislocations have complicated mining operations so that notwithstanding the richness of the veins, superintendent and foreman must have been kept in continued uncertainty and anxiety; and it is small wonder that more than one of the broken segments was overlooked in the first exploitation, and left to reward the systematic explorations of later date. At one place on the 430-ft. level of the Bodie, where both the later series cross the Fortuna, the latter is cut three times in the same plane in the same cross-cut. It is easy to imagine the excitement that must

have reigned when what probably appeared to be three parallel veins, all of great richness, were exposed at short intervals in this one cross-cut.

As will be seen in Fig. 1, the Fortuna is the only vein with marked easterly dip. It is also the only one presenting the characteristics of a strong, deep-reaching zone of fissuring. Unfortunately, this permanency is of structure alone, and does not extend to the contents; for in the lower portions the vein rapidly becomes impoverished; sphalerite, from being almost absent, increases to a large percentage; gold values weaken and almost die out; and silver diminishes to a few sparse patches of wire in masses of impure, bluish white kaolin.

Near the lower boundary of the "bonanza" zone, a vertical vein, the Beehive (Fig. 1), characterized by extraordinary silver-contents, drops from the Fortuna. Only a few inches in width and cased in hard rock, it was worked with profit some 150 ft. down. In the bottom it became poor and dwindled to a mere "marker." Here we have a notable occurrence: a vein carrying good gold-values (the bullion ran from \$9 to \$10 per oz.) is robbed of all its gold, and much of its silver, by a "dropper" characterized principally by silver, which itself soon "peters out," as regards both fissure and contents—while the original vein continues down into the earth as a well-defined fissure, marked by extensive decomposition of the walls (a feature noticeably absent above, where flat stopes now stand open over large areas, with no sign of weight on the few scattered old timbers).

The Fortuna has been explored below the bonanza zone by at least three levels and their connecting raises, and has proved barren for a considerably greater distance on the dip than was productive above.

But the problem presented by the Fortuna is not yet fully stated. The bonanza region of this vein was most strongly developed and richest where the veins of the other series intersect it, though rich ore was found not alone on these lines, and it does not appear to have been essential that the bodies in the later series should extend down to the Fortuna. To state the situation otherwise, the Fortuna has always yielded fine ore at zones of intersection with the two junior series, when those series carried ore-bodies above, whether the junior did or did



not extend to the horizon of the Fortuna. Rich zones have been found on the Fortuna equally up and down the dip from the intersections. It should be added that in all cases which I have seen, the Fortuna retained its characteristic flint-like frozen quartz, and the junior veins their characteristic banded, more porous quartz. At the same time, rich ore has been found in the Fortuna 100 ft. or more from any vein-crossings, as, for instance, in the zone above the Beehive, east of any profitable veins of the Incline series.

This generalization regarding ore-occurrence was acted upon to good advantage soon after the consolidation of the Bodie with the Standard. The Fortuna had been considered unprofitable, and, indeed, had scarcely been recognized within the Standard territory. On the south line it showed as a most unpromising seam of white quartz. Having in mind that its strike would bring it under ore-bodies then being worked in the Burgess and Maguire veins, a drift was started which, in due time, opened up profitable stopes.

A final feature of interest in this vein is to be found in the internal crossings, or fractures, occurring within the body of the vein itself, and not extending far, if at all, into the walls. In most cases these represent lines of enrichment on one side or the other; if the stope is looking well one of these crossings is likely to "queer" it. From Fig. 2 a fair general idea can be gained of the appearance of a face in a Fortuna stope.

The above observations indicate that if there was secondary enrichment resulting from the intersections of the veins, it could not have been from the senior to the junior veins. That there was an enrichment seems probable, from the association of the ore-bodies; and it is not unreasonable to suppose that, since the bonanzas in the Incline and Burgess series were in the oxidized zone, a transfer of metal-contents from the surface would be likely to occur, passing downward into the underlying Fortuna, and that the currents would be likely to follow the lines of fracture in that vein now showing in the crossings, particularly as the general physical character of the vein is "tight." It seems probable, therefore, that the Fortuna was originally a silver-vein, with values derived from below through the Beehive, and that the extinction of gold-contents below the Beehive is merely a coincidence of the location of that

vein at the lower line of secondary enrichment, which in turn may have been determined by the ground-water level, to-day not far below this point. This presents a fair working-theory, and one that in the main "holds water," though it gives no explanation of the thick mass of decomposed rock disclosed by the deeper workings on the Fortuna vein.

The profitable zone of the Fortuna is not more than 1,000 ft. long; to the northwest the vein has never been identified with certainty north of the Standard shaft, though there is in the territory of the New Standard a nearly vertical vein of similar appearance from which ore has been taken in small amount. To the southeast it has been followed far beyond the Mono

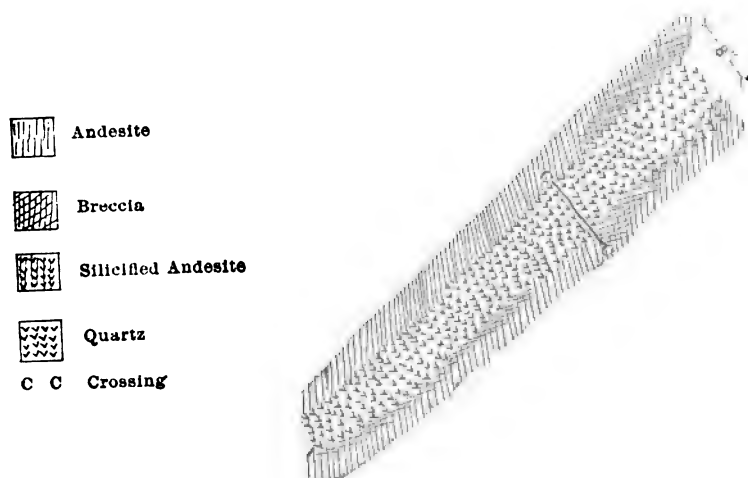


FIG. 2.—FACE IN A FORTUNA STOPE.

shaft into a region of decomposed andesite, indicated on the surface by the gulch and depression in the ridge between the Mono shaft and that of the old Champion.

One can hardly leave this subject of the much-faulted Fortuna without pointing out the seeds of legal complication which have here failed to germinate. Had erosion proceeded a little further, and had unhappy "A" located on an Incline vein (Fig. 1) and equally unhappy "B" located on the Fortuna just to the west, and yet more unhappy "C" located on the Moyle foot-wall, it is hard to see where conflicts of title could have stopped among the entangled extralateral rights and artificial end-lines. As a matter of fact, I know not how, under the

conditions that actually obtained, litigation was escaped. The Fortuna apex had not been identified, but six or eight narrow locations were made over it, on the veins of the junior series. It was a rare piece of good fortune for the mine and the camp that these were merged into the property of the Bodie Consolidated Mining Co.

*The Incline Series.*

An idealized cross-section, Fig. 3, shows the striking structural features of the veins of this system. More than once they

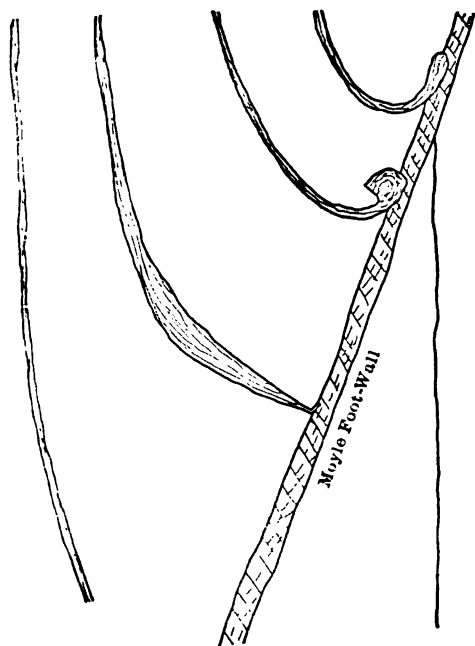


FIG. 3.—CROSS-SECTION OF THE VEINS OF THE INCLINE SERIES.

have been classed as gash-veins, in distinction from fissures, and it may be that this is the case, though the evidence is not all that way. Their marked characteristic is the fading-out of values at about the 500-ft. horizon, but I do not know of a single instance where the continuation of the vein has been disproved, while in one case, at least, that of the Gildea, the vein is found in normal width and appearance below the Fortuna, at some 700 ft. depth. As we now see them, many of this series have no chance to reach depth, being cut off by the great

fault-line, called the Moyle foot-wall. There is nothing to show the extent of motion on this fault, but while it has apparently been large, since the zone of comminution is thick, running from 10 to 40 ft., and many of the veins are curled up on it in great masses of broken quartz (Fig. 3), evidence from the Fortuna region, to be given later, is contradictory. As an argument for the gash-vein hypothesis, it should be noted that there are no veins below this fault corresponding to the Incline series above.

There is some evidence that there are at least two groups of different age included in the Incline series. This is found in the marked dissimilarity of the vein-filling. One set is characterized by massive beautifully banded flint-like quartz, at times in a firm vein and at times badly cracked, but always associated with quantities of red ocherous clay, such as would be derived from wall-attrition in feldspathic rock. Fine sharp chips of the same quartz can be washed from the mass, and there is little doubt that the values this stuff carries come from these chips. In these veins rarely are both walls well defined. The Main Standard and Incline veins are instances of this group. The other is characterized by less clay and by well banded, rather porous quartz, noticeably soft and at times crumbly, as if crushed by weight rather than attrition. I have come across no intersection that would decide the question of contemporaneity, but in some instances the two sets are close neighbors, as is the case with the Incline and the Bullion. Here it seems unlikely that had the Bullion existed at the time the Incline was grinding on its walls, it could have escaped. The probability clearly is that the Incline series is composed of two groups, if not three. Accepting this, it is to be noted that in the later group there is a sparse scattering of black oxide of manganese; in one vein indeed it was such a marked presence that the name Black Ledge came as an inevitable consequence.

I have said that the values in these veins fail at about the 500-ft. horizon. This is the lowest level at which veins of this series have been profitable and the general average would be 100 ft. higher. This unfortunate fact has been largely offset by the multiplicity of veins, and the regularity with which ore-shoots parallel each other in different veins in the pay-zone. Many times has this recognized condition been the basis of

profitable development—*e. g.*, the discovery of an important ore-body by a cross-cut, run on the 318-ft. level to cut a vein that showed nothing of value on the level below, merely because parallel veins had turned out well.

In veins of the later group of this series it is difficult to determine the value of the ore by inspection, though gold shows readily in the horn. Indeed, it was for a long time obscure to me what caused the sudden fall in values, often occurring in raise and stope in their upward course. Many times it happened that we got into old workings and found the top of the stope with a good face of fine-looking quartz that would assay but a dollar or so; and it was only by the closest inspection of the physical conditions that the question was answered and incidentally many thousand dollars more won from the mine. In all of these cases small veins or "enrichers" have been found branching off, generally into the foot-wall, and carrying very high values. These were followed, some hundred feet or more at times, each yielding perhaps half-a-ton of high-grade rock per man per month. The presence of these "enrichers" once established, it was comparatively easy to identify them in the poorer mass of the vein below. Fig. 4 shows a typical instance of what I have described, and clearly indicates that veins that were very low grade at first have been enriched by the later formation of small high-grade seams in their mass. That these are not confined to the older veins, but branch out and up into the country-rock, argues that they are veritable later veins, and not merely segregations by surface-leaching from the original contents of the larger veins. Their smallness and high grade would seem to point to their belonging to the Burgess series, which remains to be described. But, having some of the Burgess characteristics they lack others—namely, the coarseness of the gold and the character of the quartz. Moreover, no noticeable faulting is accomplished by them; so that I rather think they constitute a third group of the Incline series.

It must not be understood that all the veins of the second group of the Incline series owe their chief value to these "enriching" seams; that they do not there is abundant evidence.

All the veins of the Incline series dip west. The typical width is from 14 to 20 in. Their walls are well defined and

good. In their neighborhood the country andesite is thoroughly oxidized, unlike the andesite around the Fortuna, which, even at high levels and when much decomposed, shows no iron stain and exhibits bright crystals of pyrite. A few unimportant individuals of this series lie below the Moyle foot-wall. The albite crystals alluded to were found near the surface in veins of this series. Another mineral peculiarity was a

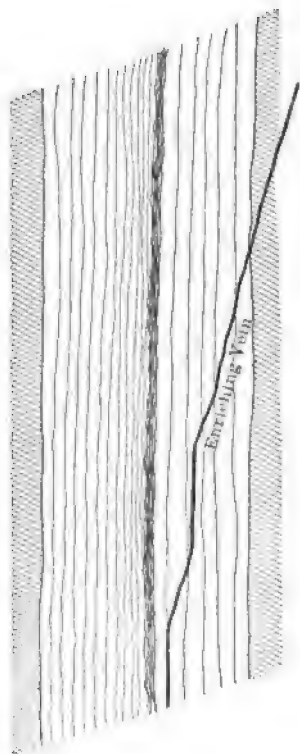


FIG. 4.—TYPICAL ENRICHING VEIN.

local occurrence of nearly pure crystalline calcite, filling the full width of the Bullion vein, on the 260-ft. level.

#### *The Burgess Series.*

If we exclude the "enriching" veins from this category, as seems proper, all of these veins lie below the Moyle foot-wall. They are small, nearly vertical veins, characterized by a slightly banded structure, at times comb-like on an axial line and frequently with a rich scale of hard quartz frozen on one of the walls. This is so important a feature that many of the old

stopes have been cleaned out and the scale removed by "pop shots" and moyle-and-hammer work at good profit. There is also at times a remarkable occurrence of "shale" on one of the walls that is an unfailing indication of rich rock. What this is, I am not sure: it has the appearance of a dried clay, mixed with sand, and shows in films, say one-sixteenth inch thick, suggesting an attrition-product. The wall-rock of these veins is noticeably less oxidized than that of the preceding series—naturally so, when it is remembered that few of these reach the surface, so that down-flowing waters are diverted into the more permeable fractured zone of the Moyle foot-wall. So rich have been some of these seams that more than once has a width of 0.5 in. been worth stoping. On the other hand, though the veins are characteristically narrow, at times values have been found some distance out in the country-rock. This was notably the case with the Burgess bonanza, discovered on the Bodie 300-ft. level, south of the Standard line. The late John Broderick, for years foreman of the Bodie, told me that when this was discovered the miners were preparing to discard the "porphyry" as waste, when he detected in it a generous sprinkling of coarse gold. This bonanza was mined for some 12 feet in width, and its location, only some 30 feet above the Fortuna, makes it probable that its richness was due to secondary enrichment from upper portions of the Burgess, according to the hypothesis already proposed regarding the enrichment of the Fortuna.

Not infrequently, angular pieces of andesite are found entirely surrounded by the vein quartz. The andesitic breccia, which has been mentioned as found at times in one of the walls of the Fortuna, is here also in evidence, and sometimes contains chips of a close-grained, coal-black rock, which does not occur in massive form elsewhere in the mine or neighborhood. No microscopic determination has been made of it, but macroscopically it would be considered a basic trap. It has clearly been picked up from some distant rocks by the viscous breccia.

The veins of the Burgess series have not been profitable for so great a distance along the strike as those of the Incline. Their "pay" has been included between east and west planes some 600 ft. apart, as against 3,000 ft. for the Incline. About 1,000 ft. on the Fortuna has been profitable.

## THE MOYLE FOOT-WALL.

Little remains to be said of this. It shows now as a scarp from 10 to 15 ft. high, west of the Standard shaft, where the ground has settled on to the big stopes. This scarp extends for 1,500 ft., and is a striking feature of the topography. Underground, the action of the fault has been to roll up the ends of the veins it cuts into big arches of crushed ore. (See Fig. 5.) To the north it dies out in the dead zone, but what becomes of

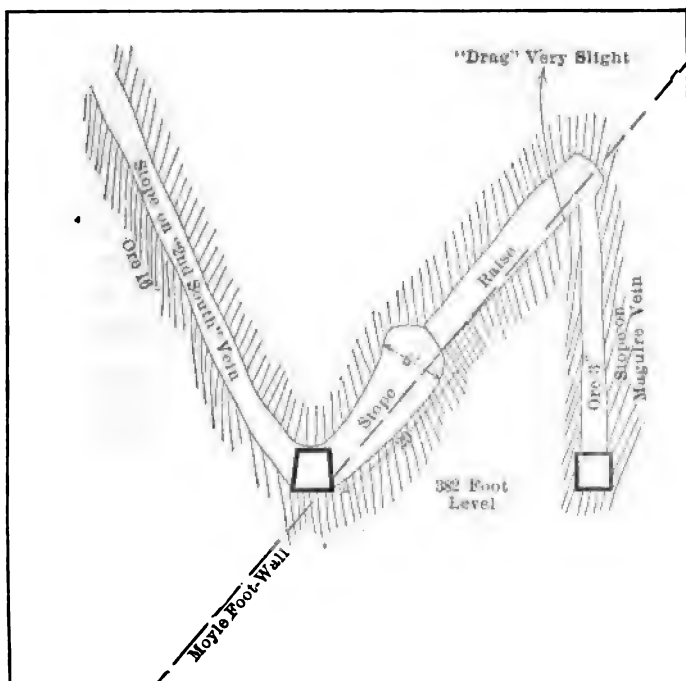


FIG. 5.—EFFECT OF THE MOYLE FOOT-WALL UNDERGROUND.

it to the south is still a matter of speculation, as its intersection with the Fortuna, which it must fault, has not been identified. I rather think that this obscuration may be because it has followed the line of some other vein in crossing the Fortuna. If that is the case, the dislocation has not been great; and even allowing a gyratory motion on the fault—and some facts point to this—it cannot have been an extensive motion. This point has already been touched upon in the description of the Incline series.



### THE DEAD ZONES.

There are two dead zones lying east and west across the andesite ridge, one to the south of Mono shaft, and the other some 2,500 ft. north and 800 or 900 ft. north of the Standard shaft. Both of these show on the surface as depressions and gulches on the westerly slope. Underground, they are characterized by heavy decomposition of the country-rock, and within their area no ore has been found, and most of the veins deteriorate to mere discolored seams. In the southern one, exploration on the Fortuna has been pressed for a long distance, yielding in places fine crystals of gypsum, evidently a secondary product. In this connection it should be remarked that in the Gildea vein small plates of the same have been found. It is probable that these zones have been determined by fracture lines, along which the rock has been brecciated. The absence of quartz-fragments argues that these fractures antedate the Fortuna, and the fact that the Fortuna and other fissures weakly enter the zone is what would be expected, for no fissure or line of circulation could be conceived as staying open in a pulpy mass such as this is to-day. Beyond the northern one of these zones, the veins come in again of good value, but in transit they have lost their identity and generally reversed their dip; the other characteristics are unaltered.

### DIKES.

No careful study has been made of these, since they do not seem to have affected the mineralization. The principal one is the "Red Ledge," a breccia too decomposed for easy determination. Where it cuts the Fortuna it is about 4 ft. wide, and stained red. Assays of from 40 to 60 cents gold per ton are common from it. No intersection with veins of the other series has been developed; hence its true chronological position cannot be assigned.

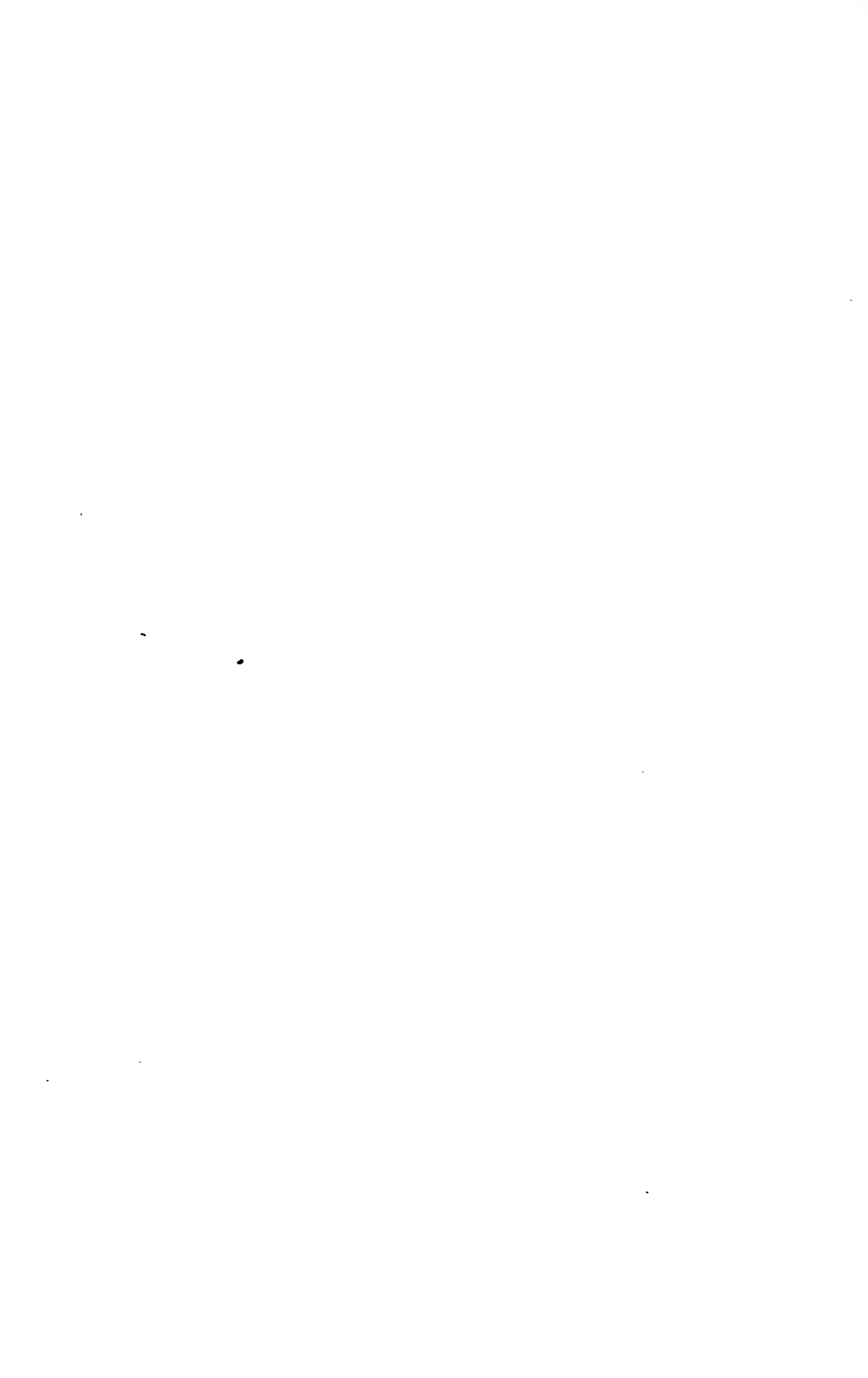
### AIR-CRACKS.

Open air-courses in the country-rock are common, particularly in the northern end of the territory; these may show a slight faulting of the veins. They have been found up to 6 in. in width, with an air-current strong enough to extinguish a candle, and have been sufficiently frequent to assist effectively in ventilation. The deepest one of which I have record was some 300 ft. from the surface, east-and-west in course and nearly

vertical. They represent the last of the fissuring periods by which the ridge has been visited, but it is not safe to assign to them off-hand the same deep-seated causes. Where they are especially prominent the ridge is nearly 1,000 ft. above the canyon, and precipitous, so that they may easily be due to frost and the settling of the rock towards the free face of the end of the ridge.

#### RÉSUMÉ.

In this interesting vein-system, we have within an area 1,000 ft. by 4,000 ft. eight or nine successive sets of fissures, five of which are ore-bearing. The Fortuna series, the oldest, is much faulted, and probably was originally a silver-vein, and owes its chief gold-contents to secondary enrichment from the faulting veins. The Incline series comprises three groups, part of the value of the second coming from the small enriching seams of the third. The Burgess series is still later. Beside these there are the great fault of the Moyle wall, the dikes, the dead zones and the air-cracks, most of which are so interlocked and crossed as to give definite evidence as to their relative ages.



## Laboratory Experiments in Lime-Roasting a Galena-Concentrate.

A Discussion of the Paper of H. O. Hofman, R. P. Reynolds and A. E. Wells, read by title at the London Meeting, July, 1906; presented at the New York Meeting, April, 1907, and printed in *Bi-Monthly Bulletin*, No. 13, January, 1907, pp. 37 to 52.

GEORGE A. PACKARD, Boston, Mass. (communication to the Secretary\*):—The very interesting results obtained by Prof. Hofman and his assistants came to my attention when I had temporarily assumed charge of the metallurgical department of the Missouri School of Mines, and had found it, pending the completion of a new building, lacking a furnace in which to roast ore preparatory to the customary lead blast-furnace run. An attempt at lime-roasting had been already determined upon, but the use of a charge which would make a slag of definite composition was a new idea. The results following were obtained by Messrs. Aubrey Fellows, J. C. Long, E. R. Wash, and Dr. T. C. Tseung, under my supervision. It is regretted that the data are not more complete; but the work was done simply incidentally to securing the desired ore for the blast-furnace, with no idea of obtaining any results of especial interest. It is submitted because of the metallic lead obtained, no notice of which has been seen elsewhere.

The ore was an aggregate of several lots of concentrates, apparently from Missouri ores. The analysis follows, with that of the limestone and sandstone used, as far as made: Ore,  $\text{SiO}_2$ , 3.04; Fe, 0.77;  $\text{CaO}$ , 2.53; Pb, 68.74; Zn, 5.77; S, 13.9 per cent.; limestone,  $\text{SiO}_2$ , 1.0;  $\text{CaO}$ , 54.35 per cent.; sandstone,  $\text{SiO}_2$ , 99.8 per cent.

The converter was made in the shops from a sheet of No. 14 iron riveted in the shape of a truncated cone, 20 in. in diameter at the top, 15 in. at the bottom and 22 in. high. A grate of No. 8 iron, 17 in. in diameter, with 130  $\frac{1}{8}$ -in. holes placed at about 1.25-in. centers, was held in place by the shape of the

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\* Received April 12, 1907.

converter about 4 in. above the bottom. This converter was set over a low brick flue, 9 in. square, into the bottom of which air was delivered by a 1.5-in. air-pipe. After the first run the air was supplied by a Laidlaw-Dunn-Gordon compressor having an 8-in. stroke and a 13-in. cylinder, running 120 to 132 rev. per min. All of this air passed through the ore excepting what a 0.5-in. pipe would deliver to the hood to carry off the fumes by forced draft.

The arrangements for starting the roast were the same as described by Prof. Hofman, excepting that coke was used in place of charcoal in the first run.

The first charge was made up of 229 lb. of ore with 20 per cent. of limestone and 20 lb. of silica, giving a silicate degree of oxygen of base to acid of 1.6 to 1. Ore, lime and silica were mostly of 3-mm. size, but all contained perhaps 10 per cent. of larger-sized slab-shaped pieces which had passed the rolls set to  $\frac{1}{8}$  in. Coke was used in place of charcoal for starting the reaction. In this case the air was supplied, through a connection with a furnace-tuyere, from a No. 1 Baker blower, and not over 4 in. of water-pressure was obtainable.

Sulphurous fumes were evolved slowly and the total time was about 2 hours, though but little sulphur was noticeable after 35 minutes. Examination of the resulting mass showed it to be only partly sintered and but 15 per cent. of the sulphur eliminated. Evidently finer crushing, more blast, or some other change was necessary. After picking off all the adhering coke this whole mass was now re-crushed to 3-mm. size, and again charged into the converter, the compressor supplying air for the second run. The only difference in composition between this and No. 1 was the small amount of sulphur expelled, and an increase of perhaps 50 per cent. in the limestone from that used under the first charge which adhered to the sintered mass and was re-crushed with it. The result showed the sulphur in the charge reduced to 2.6 per cent., but a large amount of metallic lead was obtained. This was not separated, but was estimated to be equal to at least 10 per cent. of the total lead in the charge.

A series of experiments was now undertaken with a view to obviating this difficulty. While it is possible that the lead might be reduced by the action of lime, it seemed probable

that owing to the small amount of silica present, about 8 per cent., the reactions were those of the "roast and reaction process," the lead sulphate and oxide reacting with the sulphide to give metallic lead. These experiments were carried on in a clay crucible similar to that used by Prof. Hofman, and 1 kg. was the unit of ore used.

Series A was run with low silica, about 9 per cent. of the charge, and 40 per cent. of limestone, having an oxygen ratio of base to acid of 1.5 to 1. The pressure varied from 2 in. to 8 in. of water. The amount of lead obtained in the metallic form on a 100-mesh sieve varied from 0.11 to 2.85 per cent. of the total lead present, the highest with the lowest pressure.

Series B was run with low silica, about 9 per cent. of the charge, but only 20 per cent. of limestone added, giving approximately a singulo-silicate ratio when the lime in the ore is included. The result was, from 1.43 to 3.03 per cent. of the total lead was obtained in metallic form, but in this case the highest per cent. was obtained with the highest pressure.

Series C was run with high silica, 17 per cent. of sandstone added, and enough lime to give a singulo-silicate ratio, including the silica and lime in the ore. In this series no metallic lead was obtained.

A single additional experiment, with 12 per cent. of sandstone added and limestone proportioned as in series C, gave 0.39 per cent. of metallic lead on a 100-mesh screen.

The amount of sulphur eliminated varied in the tests from 48.8 to 75.5 per cent., though it was below 61 per cent. in only two out of ten runs. Our results in this connection seem too variable to serve as a basis for conclusions as to the effect of varying pressure, especially in the cases where metallic lead was obtained. The same condition seems to exist in the results published by Prof. Hofman. Thus 4, 4a and 4b, using 10-, 2- and 10-in. pressure respectively, show less variation between the first 10-in. pressure and the 2-in. than between the two having the same pressure. In our series, with no lead formed and pressure being 3.6, 6 and 9 in., we obtained an elimination of 61.9, 65.9 and 73.8 per cent. of sulphur, but working in these small crucibles it seems possible the amount of charcoal present at the start might affect results. We might also add that the desulphurization was quite as good in series C with high

lime as in B with low lime. But here again we have another variable, as the silica was also increased.

For us, the most practical result of these tests was the elimination of the metallic lead, a result which was confirmed by three subsequent 300-lb. charges in the sheet-iron converter, using 15 per cent. of silica in the charge.

Our conclusions were, that with this ore, with less than 12 per cent. of silica present, a considerable amount of metallic lead might be obtained; and also that our results on this ore did not confirm the results obtained by Prof. Hofman on the Cœur d'Alene ore as to the percentage of lime and the pressure giving the best desulphurization. Whether, in working on ores very low in silica the amount of metallic lead might be increased to a point where this lead would be a product worthy of separation would be interesting to know.

H. O. HOFMAN, Boston, Mass. (communication to the Secretary\*):—The conclusions arrived at by Mr. G. A. Packard in his experiments of lime-roasting a galena-concentrate containing  $\text{SiO}_2$ , 3; and Pb, 69 per cent., bring out several interesting points.

In showing that it requires the presence of 12 per cent. of silica to prevent the liberation of metallic lead, he calls to mind a similarity between the results of lime-roasting and slag-roasting the same class of ore in a hand-reverberatory roasting-furnace.

When I was connected with the smelting-plant at Mine La Motte, Mo., in 1881, it was necessary not only to add enough silica to the galena-concentrate to obtain a roasted product with 15 per cent. of silica, if the separation of lead was to be avoided, but to give special attention to a careful mixing of ore and sand, and to a thorough rabbling while the charge was passing through the furnace, as some lead would separate out in spite of the large addition of sand, if these two points were not attended to. An examination of the older analyses of slag-roasted ore and of the more recent ones of ore that has been only agglomerated reveals the fact that the quantity of silica rarely goes below 15 per cent.

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\* Received May 8, 1907.

This intimate contact of silica and galena being essential for satisfactory work in the hand-reverberatory furnace, furnishes one important reason, of the many that are possible, why the results in lime-roasting a galena, with 6.5 per cent. of gangue, of which 3 per cent. is silica, when mixed with sand may differ from those of a galena-concentrate containing 33 per cent. of acid gangue, of which 18.6 per cent. is silica.

The idea, suggested by Mr. Packard, of lime-roasting a galena-concentrate very low in silica without the addition of siliceous matter, with the object of recovering part of the lead in the metallic state, does not appear to offer any advantages on account of the inherent loss of lead by volatilization, the imperfect elimination of sulphur, and the difficulty of recovering the metal.

As soon as metallic lead separates out in slag-roasting, the fumes passing off by the chimney show this at once. The loss is sufficiently large to have prompted the uniform practice of avoiding it. Something similar will occur in lime-roasting. Even supposing the separation of lead to be permissible with non-argentiferous galena, it would be inadmissible when the galena carried any silver, as the loss in precious metal would be too great.

In lime-roasting, the charge becomes scorified; and scorified material gives an imperfect reduction of lead oxide and lead sulphate by lead sulphide; hence the elimination of sulphur by the operation would be unsatisfactory.

There is, finally, the difficulty of separating the metallic lead from the lime-roasted ore. While some of it may trickle down through the charge, and, after passing through the openings in the grate, may be removed from the bottom of the converting-vessel, the bulk will remain disseminated through the roasted material. As this has to be smelted in the blast-furnace, there will be a decided loss in lead when the charge descends in the furnace, which everybody has experienced who has been forced to add bars of lead to his smelting-mixture in order to keep hot the lead in the crucible.





## Piping and Segregation in Steel Ingots.

A Discussion of the paper of Professor Howe, presented at the London Meeting, July, 1906, and printed in *Bi-Monthly Bulletin*, No. 14, March, 1907, pp. 169 to 274.

SECRETARY'S NOTE.—M. Beutter's introductory remarks, being simply a *résumé* of Prof. Howe's paper, with a disclaimer of the intention to criticise it, have been omitted, and the remainder of this contribution has been somewhat condensed, without omitting any essential statements.

M. BEUTTER, St. Etienne\* (communication to the Secretary) :—Professor Howe observes in paragraph 47 of his paper that the fluid-compression of steel diminishes piping by forcing the liquid and viscous metal, while the pipe is forming, or after it has formed, into the space so produced, and proceeds to study the different systems of compression, alluding to the four principal ones: Whitworth, Illingworth, Williams, and Harmet.

Having now for many years had in use the last-named process, that of M. Henri Harmet, I shall attempt to explain the difference between it and the three other processes named.

The Harmet process does not diminish or close the pipe after it has formed, but prevents it from forming; and I may add that it is the only one of the four which produces this result.

It is true that the Whitworth process diminishes the interior hollow by localizing it around the central axis of the ingot, which is afterwards removed by trepanning the hollow forgings for which this process has been, I believe, always exclusively used. The Illingworth and Williams processes, which, in my opinion, are applicable only to small ingots, of necessity allow the pipe to form, or (to use the expression of Professor Howe) they allow the surface of the lake of liquid steel to sink into the interior of the ingot, since they involve waiting a certain time before compression, so that (in the case of the Williams process) the ingot-mold can be opened without danger, or (in the case of the Illingworth process) so as to avoid the risk that the steel may enter the grooves produced by the removal of the distance-bars. During the time required for

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\* Chief Engineer at the Fonderies, Forges & Acieries de St. Etienne.

† Received Jan. 25, 1907, and translated by Franck E. D. Acland.

the formation of the exterior skin of the ingot the level of the interior lake of steel has certainly sufficient opportunity to sink; and compression, ultimately applied, by either the Illingworth or the Williams process, can result only in raising more or less the level of this lake into the hollow parts already formed above it. But it is also certain that this liquid lake, as it ebbs from its banks, will have deposited upon it impurities, which may afterwards prevent the intimate combination of the mass with the new steel which will subsequently rise over them. Ingots so produced may possibly appear perfectly sound, but will certainly present a zone of weakness, corresponding, in the imagery of Professor Howe, to the banks of the lake of steel at its different levels, or the pocket which has been allowed to form and afterwards closed. Professor Howe clearly shows that the operation of compression ought to commence as soon as possible after casting, so as not to allow the level in this lake to fall and then again to be forced back—such a movement of the steel being clearly detrimental.

This evil does not exist in the Harmet process, which, as already explained, does not close up a pocket already formed, but prevents its formation by effecting the lateral compression of the metal immediately after casting. By reason of the conical form of the ingot-mold, it is not necessary to open the mold in order to commence operations, and consequently to wait until an exterior skin or crust is formed, during which delay an interior hollow has begun to be developed. In our own practice we have found that, with certain hard steels, it is practicable and advisable to begin compression by forcing the ingot through the mold while casting is still going on. In the steel-works at St. Etienne, an ingot is rejected as bad, if for any reason the operation of compression was not commenced upon it at once, even though it is possible that such an ingot might not show a pipe or pocket if a section were made of it. This point is illustrated by Fig. 1, representing the photograph of an ingot sectioned through its longitudinal axis. In order to produce this result we intentionally waited some time after the casting before commencing compression, doing our utmost to bring about conditions similar to those produced by the Illingworth and Williams processes, which cannot possibly commence compression at once. When sectioned, this ingot appeared to

be perfectly sound ; but, after a treatment with acid, the shape of the primary pipe, afterwards filled with metal forced into it by compression, was very clearly revealed. The photograph shows also that the whole axis of the ingot has been subjected to an upward movement of the liquated metal towards the pipe at the top. The axis of the ingot remains porous, and the treatment by acid reveals perfectly the manner in which the metal flowed.

Ingots compressed by the Harmet process, in which the pipe is never allowed to be produced, show, after treatment with acid, a remarkable solidity and compactness, without any trace of a zone of weakness. This Harmet process continually keeps the skin of the ingot absolutely full, and even slightly flowing out of the top.

The conclusion of Prof. Howe, that the Harmet is less effective than the Williams process, seems scarcely fair. His reason is, that the latter process squeezes the ingot at the center of its length only, thus allowing the metal to rise more readily, in order to fill the void above.

But since, in the Harmet process, the ingot is kept always full and compact, there must be an advantage in squeezing it uniformly and at all times over its whole surface, utilizing fully the wedge, due to the conical mold, and thereby energetically compressing the metal to its center, so long as there remains a single drop of liquid steel—thus producing, in consequence, ingots absolutely homogeneous and compact from center to surface, and from top to bottom.

Ingots produced by this process are not only physically sound, without any interior hollows, but also, to a remarkable degree, chemically homogeneous. Liquation is not produced, because the process furnishes the chief conditions specified by



FIG. 1.—SECTION OF AN INGOT, SHOWING EFFECT OF DELAY IN COMPRESSION.

Prof. Howe himself as being necessary to prevent this phenomenon.

Professor Howe points out as the means to avoid liquation : (1) casting at low temperature ; (2) casting small ingots ; and (3) employing thick molds, not lined with sand, and pre-heated. The temperature at which steel is cast is, and should be, independent of the method of compression employed, but both the other conditions named are fulfilled in the Harmet process. In fact, thanks to the absolute soundness of the ingots, produced by tremendous squeezing in the passage of the metal through the conical mold, it is possible to produce from our compressed ingots forgings such as ordinarily require the casting of larger ingots, and thus to dispense with much of the heat-treatment and forging required to put into proper molecular condition ingots which have not been so compressed. Finally, the molds used in the process are necessarily thick, on account of the energy which they have to transmit. They cool very rapidly ; and it is our common practice to assist this rapid cooling with water, which pours continuously down the mold and over the hoops which reinforce it. From both points of view—namely, that of piping and that of liquation—the Harmet process thus fills all the conditions desired.

On the other hand, the Whitworth process attacks the ingot in the direction of the length, in which it must present its greatest resistance ; causes it to be distended outwards from the center, in a lined mold which does not assist the cooling ; and results in producing ingots in which the axis is unsound, and which are used only for hollow forgings ; whereas, the Harmet process attacks the ingot throughout its length with the whole lateral effort resulting from a conical mold, and, thanks to the thick iron mold, which cools very quickly, produces ingots sound and perfect throughout, and available, without waste, for forgings of the highest quality, such as armor-plates, guns, shells, and complicated cranks.

The foregoing statements and claims are not made upon theoretical grounds only, but can be verified by the records of daily practice at the steel-works of St. Etienne and other European establishments where thousands of ingots, widely known for their homogeneity, have been regularly manufactured by this process for many years past.

HENRY M. HOWE, New York, N. Y. (communication to the Secretary\*):—Mr. Beuttler has completely missed the point of my discussion of the relative merits of the different methods of compression. I refer him to the first paragraph of § 62, which I think states the matter clearly, especially if taken in connection with §§ 60 and 61.

But perhaps I may recapitulate the matter by saying that what I was discussing was the efficacy with which we could make use of the pipe itself as a receptacle into which we could lift the segregate. I pointed out that in order that the pipe should be most effective for this purpose, we should leave the pipe itself uncompressed, so as to leave it open to receive as much as possible of the segregate. Compared with Williams's method, Harmet's has the disadvantage that it diminishes the pipe, not alone through lifting the segregate into it, but also by narrowing the upper part of the ingot, which contains the pipe, or at least which would contain the pipe were the pipe allowed to form. By as much as it thus narrows the upper part of the ingot, by so much does it diminish the size of the receptacle into which the segregate may be lifted, and by so much does it lessen our power to lift the segregate, and thereby to shorten that portion of the ingot which has to be rejected because of the segregate.

MR. ROBERT W. HUNT, Chicago, Ill.†:—I think the parties who have anything to do with commercial steel-products fully realize the very great importance of this subject. In fact, it is one that to-day is staring the railway world in the face with a vital importance. We read unfortunately often of railroad wrecks, which are attributed to broken rails. In a majority of cases, the rail is found to have been piped. This piping takes place to an extent much beyond what we appreciate or apprehend; for there are many thousands of rails in service which have not failed, and still have that trouble fully concealed in their interior; and these are a constant menace, being liable to fail at any time. Unfortunately, it means, in the present condition of the art, a revolution in rail-making, if this thing is met, as sooner or later it must be.

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\* Received Feb. 14, 1907.

† Oral discussion at the New York Meeting, April, 1907.

At present the element which seems to control is that of volume of production, over-controlling and over-topping every other consideration; and to say to the rail-maker that he must discard from 25 to 33½ per cent. of his ingots, is so revolutionary that it will not be listened to. But it seems to me this will have to be done, unless the difficulty can be overcome in some mechanical or chemical way. Prof. Howe, if I am not mistaken, suggests one or two ways in which this piping, and also the effects of segregation, can be minimized. But, if again I am not mistaken, he does not give us a remedy which would apply to rail-making. I think he suggests, for instance, that an ingot shall not be more than 8 in. in diameter. That, of course, is absolutely impracticable, so far as making rails is concerned. It would attack the vital condition of production, and it would give us a casting from which we could never roll successfully a 100-lb. rail, for instance.

This matter, as I have said, is of the greatest moment. Anything that tends to throw light on the existence of the disease must enforce consideration and help to bring about a remedy, even if it involves the cutting-down of production, and so an increased cost to the consumer of the manufactured rail. We cannot go on as we are doing now. We have mysterious breaks in which the rails do not show any piping, but break, apparently, without cause. Frequently, analysis discloses segregation, which perhaps sometimes accounts for the failure; but even that is not always present. The cause seems to my mind to date back to the physical manipulation of the steel during the process of manufacture.

We have gone away absolutely from the practices and traditions of the past; and the effort has been and is to get the metal into shape as quickly, and with as few applications of power, as possible. In the first place, the size of the ingot has been increased and the number of passes in the rolling decreased. If a structure, when cast in the ingot, is very coarsely crystalline, and in the finished product is much finer and more closely united—the units of crystallization having been reduced in size—it is to my mind illogical to assume that we can get the same result in that respect by forcing the change in crystallization immediately, as by giving it more time. We may effect some change in character, but is it not easy to appreciate that

the physical properties and the strength of structure may differ? Whether we can realize it or not, it is true. We have had during the past few years an illustration which, to my mind, emphatically demonstrates it. There is a rail-mill and steel-works on this continent which, after becoming superannuated, and standing idle many years, was purchased and rehabilitated, and is now running. This plant is nearer the character of the works of 25 or 30 years ago than any other in existence on this side of the water. They re-melt the iron in cupolas; and the small size of the converters, the weakness of the blooming-mill, etc., necessitate a slow reduction of the ingots to blooms, and the re-heating of these before rolling them into rails; thus making the routine of manufacture closer to that of the olden time than at any other American works. A certain railroad has had in its track more than 100,000 tons of these rails, and quite an equal quantity of rails made by other manufacturers, more nearly in accordance with the present usual course of manufacture. The figures of breakages are in favor of the old-fashioned procedure, to the extent of quite four to one; although it happens also that the chemical composition of these rails that have broken less is not as good as that of the others. In fact, the phosphorus in them had a limit of 0.085 per cent. as compared with 0.07 per cent., or less, in the others.

Prof. Howe's paper, like everything else he has contributed, has been prepared with great care, and demonstrates very clearly what happens in casting steel ingots. It is up to the people who produce to use this knowledge and this light. For one, I want to thank him very much.

Everything has been ignored lately for speed. We must get back; and if mills cannot make 70,000 tons of rails a month, and make them right, somebody has got to force them back to the quantity which they can make and make right, or else let them keep them piled in their yards, and not put them in the track to endanger property, to say nothing of human life. The whole trouble is not with the rails. Road-beds, weight of rolling-stock, speed of trains, counterbalancing of engines—all must be considered; but we know of the rail-weakness, and its correction should not be delayed while the other elements of the situation are receiving attention.



PROF. HENRY M. HOWE, New York, N. Y. (communication to the Secretary\*):—These words of Captain Hunt, than whom none can speak with more knowledge and authority on the rail-question, are full of interest, especially his belief that the quality of the rails has been lowered by the increase in the size of the ingots and the decrease in the number of passes in the rail-mill.

As regards the remedies which I have suggested for segregation, I have had too much practical experience in rail-making to be caught making so rash a suggestion as decreasing the size of rail-ingots to 8 in. This size I advised for special cases of "steel of unusual excellence, such as high-carbon steel for the wires of suspension bridges." (§ 82, p. 273 of my paper.)

In order to restrain segregation in rail-ingots I would do three things: (1) use aluminum or its equivalent freely; (2) teem extremely slowly; and (3) increase the discard. In order to increase the practicable slowness of teeming of each ingot taken by itself, without running into the danger of having a heavy ladle-skull, I would teem into two or more molds simultaneously from the same ladle, either through two nozzles or through a distributing-funnel.

As to cropping, it is idle to crop off only the ragged top of the ingot, and leave just below it the richest of the segregate, the part into which the phosphorus has been concentrated from the whole ingot. Beyond this, I would have the inspectors search carefully for the segregate in a specified percentage of the ingots made; and I would give an upper limit for phosphorus in the most-segregated part, as explained in §§ 78 and 79 of my paper.

I have expressed my views on the rail-question more fully in an article in the *Engineering and Mining Journal*, ——— ———.

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\* Received June 19, 1907.

## **The Verschoyle Pocket Transit.**

BY W. DENHAM VERSCHOYLE, BALLISODARE, IRELAND.

(Toronto Meeting, July, 1907.)

IN designing a pocket instrument whereby any given horizontal or vertical angle may be closely approximated, the following points should be kept in view, if general utility is aimed at:

1. The instrument should be light and compact, so that it can be carried in the pocket, or in a sling.

2. It should be capable of observing any angle whatever, horizontal or vertical.

3. Since time is often an important consideration in making a preliminary survey, it should be capable of giving the horizontal and vertical angle at one observation.

I do not know of any instrument that will fulfill these requirements, except the one here described.

Where the depression- or elevation-angle of the distant object, whose bearing is required, exceeds 50 or 60 degrees, it becomes difficult or impossible with a prismatic compass, for instance, to obtain accurate results; and since it frequently happens, particularly in mining, that much work requires to be done beyond that limit, it is obvious that an instrument which can be used to observe a high angle just as easily as a low one, if not absolutely a necessity, will at least be a great convenience.

How this "pocket transit" attains to the required degree of universality will be understood from the diagram, Fig. 1, in which *B* is a beveled, graduated circle, attached to and freely revolving about the center of the magnet *A*. Light falling on *B* is reflected through a window in *F* (the compass-box), along the line *AC*, and is again reflected back to the eye at *D* by the prism *C*.

By a simple arrangement, the sight-line *DCE* can be completely revolved in the vertical plane *DE*, which is normal to *AC*. It is clear, then, that no matter through what vertical

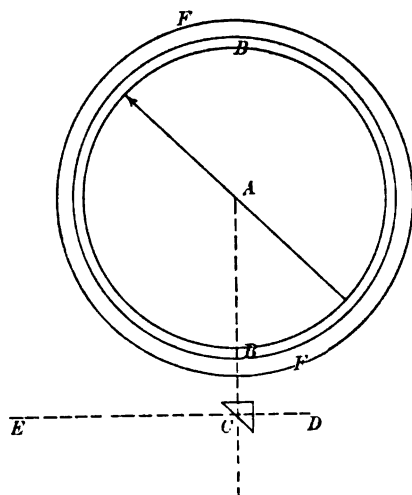


FIG. 1.—DIAGRAM, ILLUSTRATING THE PRINCIPLE OF THE POCKET TRANSIT.

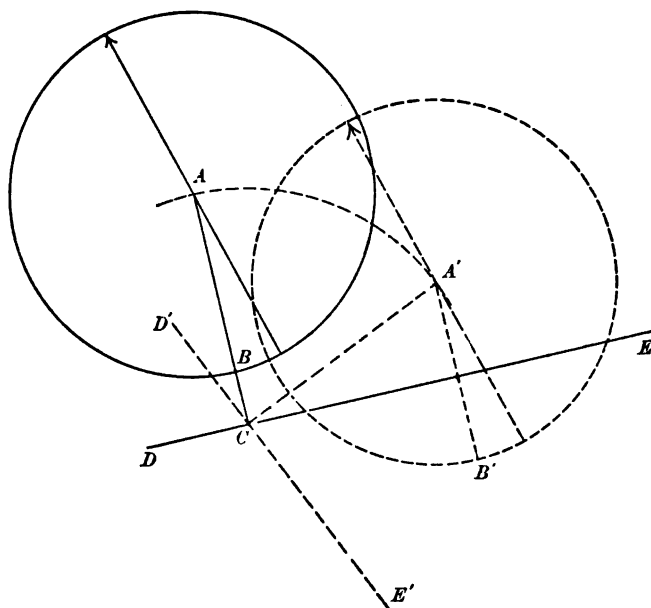


FIG. 2.—DIAGRAM, ILLUSTRATING THE PRINCIPLE OF THE DOUBLE OBSERVATIONS MADE WITH THE POCKET TRANSIT.



FIG. 3.—APPEARANCE OF THE VERSCHOYLE TRANSIT WHEN CLOSED.

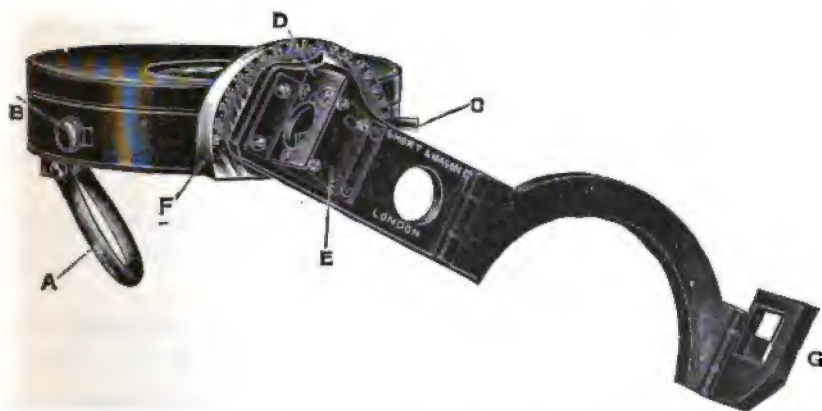


FIG. 4.—THE VERSCHOYLE TRANSIT, WITH SIGHT-ARM DEPRESSED.

A, thumb-loop ; B, needle-lifter ; C, needle-brake ; D, back-sight hole ; E, prism-box ; F, vertical arc ; G, fore-sight.

angle  $DE$  has been rotated, the figures at  $B$  can be read with equal ease, by means of the prism  $C$ . Also, by placing on the arm to which are affixed the prism  $C$ , and the fore- and back-sights defining the line  $DE$ , an alidade which traverses a vertical graduated circle affixed to  $F$ , and by having a small spirit-level affixed to  $F$ , the bubble of which is visible also at  $D$ , we are able, in observing the magnetic bearing of any distant object, to secure an automatic registration of the vertical angle by bringing the bubble to the center.

To obtain freedom for the sight-line in the vertical plane, it was necessary to make it tangential to the horizontal circle.



FIG. 5.—THE VERSCHOYLE TRANSIT, WITH ARM ELEVATED.

If, then,  $A$  were used as the center of the instrument, there would be an error due to eccentricity, in observing horizontal angles.

If, however,  $C$  be taken as center, and the instrument be considered in any two positions, the following will be true in all cases:

Let  $ABCDE$ , the plain line part of Fig. 2, represent any position of the instrument. Let the sight-line  $DE$  be moved through any horizontal angle  $ECE'$ , to the second position, as shown by the dotted line, and take  $B'$ , the same point on the scale as is cut by  $AB$ . Then  $A'B'$  is parallel to  $AB$ , and the angle  $ECE' = ACA'$ , and therefore  $= CA'B'$  (Eucl. I., 29),

which means that any horizontal angle through which the sight-line is rotated, with  $C$  as center, is equal to the angle through which  $AB$  passes, in the same motion, with  $A$  as center.

The instrument can be used as a clinometer and grading-level; and a tripod of special design is supplied if desired. To use it as a clinometer, the bottom side of the arm is laid on the surface the dip of which is to be measured, and the compass-box is slightly revolved until the small bubble, viewed through the window at the top of the box, is brought to the center of the spirit-level, when the angle may be read off the vertical arc.

Figs. 3, 4 and 5 show the general appearance and construction of the instrument. It is manufactured in the United States by the Taylor Brothers Co., Rochester, N. Y.



## **Barite Associated with Iron-Ore in Pinar del Rio Province, Cuba.**

BY CHARLES CATLETT, STAUNTON, VA.

(New York Meeting, April, 1907.)

AN examination of the census reports<sup>1</sup> for 1880, which contain a large number of complete analyses of typical American iron-ores, indicates that the existence of barium sulphate in intimate association with iron-ore is rather unusual. Of 94 analyses reported there, but four show any barium sulphate, and the maximum content amounts to 3.04 per cent. The note of the occurrence of considerable quantities of barite in connection with certain iron-ores found in the Pinar del Rio Province of Cuba may be of interest.

These deposits are found near the little village of Francisco, about 25 miles west of the city of Pinar del Rio on the Western Railroad of Havana. The principal ridges are anticlines, and consist of very thick deposits of sandy shales and slates containing a large number of little veins of white quartz which, by the gradual disintegration of the mass of the material, is left covering the surface. This quartz occasionally shows sulphide, but is generally barren of any such indication. At times lenticular masses of a more or less pure limestone were observed in these slates. The shales, which are of light color, are occasionally talcose.

The formation would tentatively be classed as the Lower Cambrian, and the heavy ridges of comparatively horizontal limestone found in the anticlinal valleys as the Upper Cambrian.

Along the crest of these slaty ridges deposits of iron-ore are found which are apparently in place, and were probably formed by replacement of masses of limestone similar to those noted elsewhere. The ready disintegration of the slates, and the

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<sup>1</sup> *Report on the Mining Industries of the United States*, Tenth Census of the United States, vol. xv., pp. 583 to 601 (1880).



fact that the only product of such disintegration which holds together in masses of any size is the iron-ore, has left the ore exposed to an unusual degree, and permitted its transportation over long distances and its concentration along certain lines of drift-flow. The masses are very striking. A number weigh 100 tons each, and one weighs between 1,000 and 1,500 tons.

The iron-ore is essentially a brown hematite partly dehydrated at points, and from the existence of stalactitic forms it frequently bears evidence of secondary water-action. The striking thing in connection with the deposit is the occurrence of barite crystals throughout the mass of ore. These crystals are occasionally in bunches of considerable size, but are very generally distributed.

The iron-ore as it passes farther from the source of its probable origin is improved in quality by the gradual breaking up of the boulders and the removal of the softer particles. The more distant collections of ore are higher in iron and lower in barium sulphate.

The following analyses are of samples of iron-ore from the principal "mines" which have been selected with a view to represent commercial possibilities :

	I.	II.	III.	IV.	V.	VI.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Iron, . . .	54.39	49.73	49.45	56.07	58.13	60.64
Silica, . . .	1.44	3.50	3.94	3.04	2.36	2.60
Phosphorus, . .	0.075	0.05	0.064	0.086	0.086	0.125
Barium sulphate,	5.36	9.20	10.00	0.20	1.20	0.64

**SUBJECT TO REVISION.**

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

**Bibliography of Injuries to Vegetation by Furnace-Gases.**

BY PERSIFOR FRAZER, PHILADELPHIA, PA.

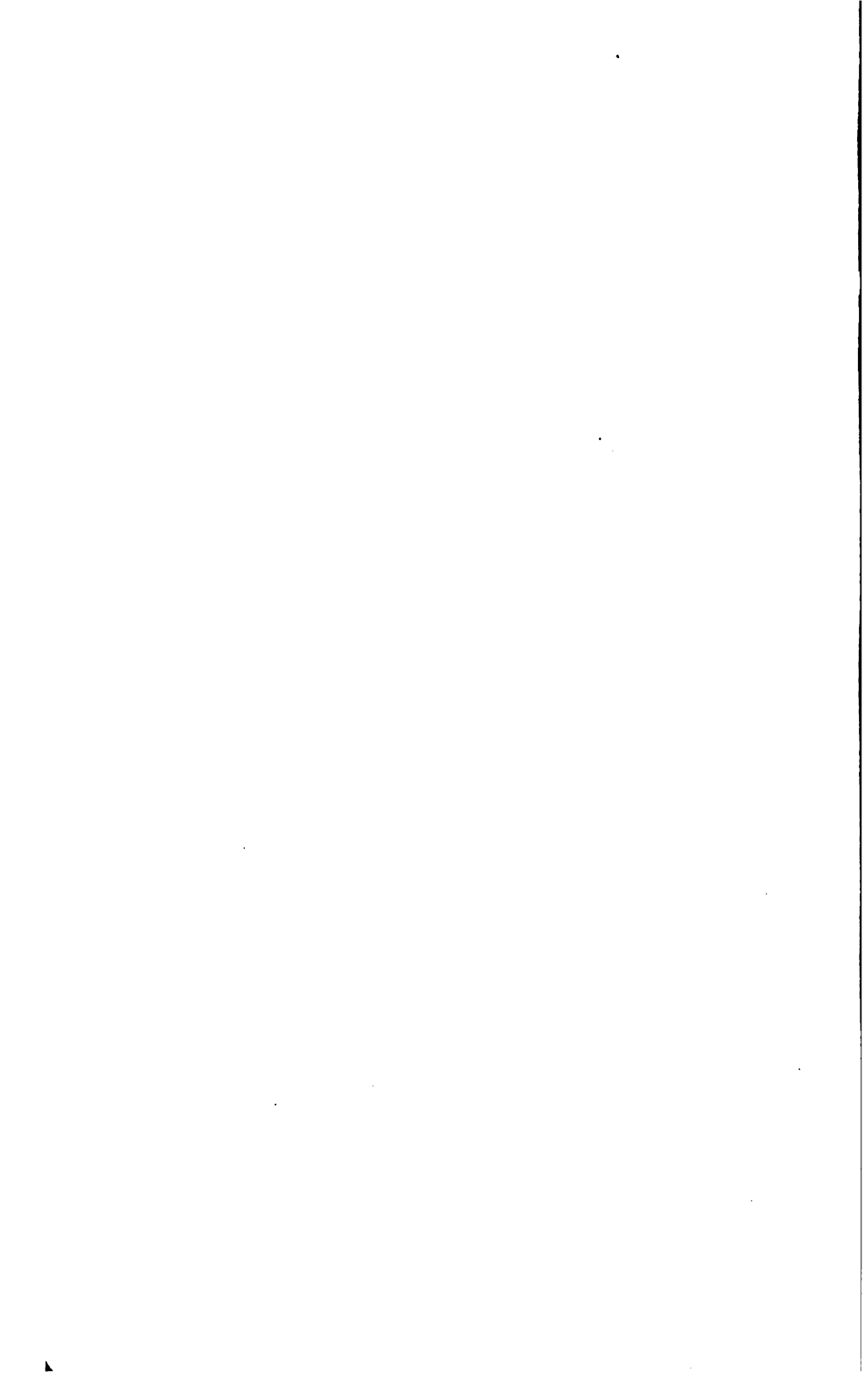
(*Bi-Monthly Bulletin*, No. 15, May, 1907.)

**SUPPLEMENTARY NOTE.**

THE two following titles should be added to the above Bibliography:

On p. 415, as No. 25*a*.—AN EXAMINATION OF THE ATMOSPHERE OF A LARGE MANUFACTURING CITY. Prof. Charles F. Mabery, *Journal of the American Chemical Society*, vol. xvii., p. 105 (1895).

On p. 434, as No. 46.—THE ADVANTAGE OF A SCIENTIFIC BASIS FOR DETERMINING THE VALUE OF FUELS. Henry J. Williams (chemical engineer), *Journal of the New England Waterworks Association*, vol. xix., No. 1. (Paper read Dec. 12, 1904. Followed by a discussion.)



## The Wilfley Table.

BY ROBERT H. RICHARDS, BOSTON, MASS.

(Toronto Meeting, July, 1907.)

THIS truly remarkable machine was built on a preliminary scale in May, 1895. The first full-sized table was built by Mr. A. R. Wilfley, and was used in his own mill in Kokomo in May, 1896. The first table sold for installation was placed in the Puzzle mill, Breckinridge county, in August, 1896.

The mill enthusiasts at first hailed it as the cure for all the ills that flesh is heir to in the milling line. A little later it was found to make losses which were serious, and on this account the table succeeded only to a limited extent in displacing the vanners of the gold-mills. Still later, mill-men in a number of districts throughout the country made special studies of the faults of the machine, and devised a number of ways of grouping supplementary machines to overcome as far as possible the losses, and at the same time retain the benefit of the extraordinarily large capacity accompanied by the production of clean concentrates for which the machine has become so justly famous. I hope to make an exhibit of some of these methods in an appendix to my book on ore-dressing which is now in preparation. These experimenters have not written up the subject, and if they possess all the facts they have not given them out for the benefit of the mining profession at large.

The object of this paper is to obtain the facts and to present them so clearly that their bearing can be seen by all. To this end two complete series of tests have been planned. One (the present paper), to study concentration of galena in presence of quartz; the other (to follow shortly), to study concentration of chalcopyrite in presence of quartz.

Some authorities claim that the table does its best work when treating natural products; by this phrase I mean products which have been crushed to pass through a limiting

sieve, but have had no other preparation whatever; in consequence they have all sizes of grains of both the heavy valuable mineral and the light waste gangue, ranging from the largest grains that can pass through the sieve down to the finest dust.

Others claim that the ore fed to a Wilfley table should be closely sized before it is fed. That is to say, it should be divided by a series of sieves ranging from coarse to fine into a series of products with sizes of grain ranging from coarse grains to fine grains; and that each of these products, in which the grains of the heavy mineral are of approximately the same diameter as the grains of the light mineral, should be fed to the Wilfley table.

Still a third group of authorities claims that the ore before being fed to a Wilfley table should be classified by a hydraulic classifier, which divides the crushed ore into a series of products ranging, like the sized products, from coarse grains to fine grains, by carrying it in a water-current over a series of apertures or vertical pipes, called sorting-columns, up through which water-currents are passing. These currents are graded from faster to slower, and therefore allow only the heaviest grains to settle down through the first sorting-column and out through the spigot, while lighter smaller grains settle in the second, and still lighter in the third, and so on, diminishing until the last sorting-column and spigot give very small grains, and the overflow has the finest grains of all. The classified products differ greatly from the sized products in that the grains of heavy mineral are much smaller in diameter than the light grains with which they settle, and therefore behave in a somewhat different way upon the Wilfley table from the sized products. It should be said that the first spigot-product of a classifier differs from the others in having coarse grains of heavy mineral present also.

The usual division of products upon a Wilfley table is easily and naturally made, as shown in Fig. 1, *A* being concentrates; *B*, middlings; *C*, tailings, and *D*, slimes. Of these, when natural products are fed, the concentrates, *A*, are nearly clean heavy mineral, a slight contamination of small grains of quartz being present. The middlings, *B*, carry some large grains and also some small grains of heavy mineral. The tail-

ings, *C*, carry some very small grains of heavy mineral, and the slimes, *D*, carry very minute grains of heavy mineral.

I believe that the small grains of heavy mineral in middlings, *B*, and tailings, *C*, are of less diameter than the smallest in the concentrates, *A*, and of greater diameter than the majority in the slimes, *D*, and that they belong in middlings and tailings from the law of their existence. The re-running of such middlings upon the same table is therefore not a wise proceeding, and only admissible as an expedient in small establishments when the quantity of middlings is not sufficient to warrant other provision. So much for the speculation before the investigation was made.

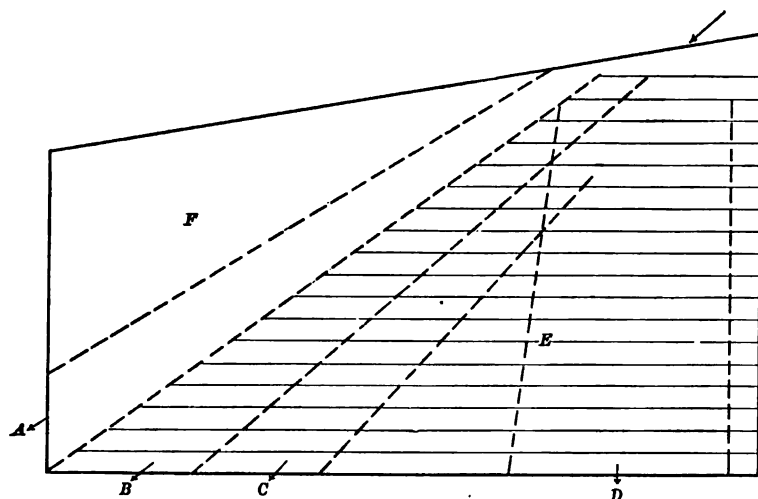


FIG. 1.—USUAL DIVISION OF PRODUCTS ON A WILFLEY TABLE.

The materials for this test were pure white massive quartz for the light mineral, and crystalline galena, nearly free from blende and other impurities, from Joplin, Mo., for the heavy mineral. The quantities of these impurities were so small as to have little effect on the results. Both minerals were broken down to 2-mm. size, and mixed so as to have approximately 10 per cent. of galena and 90 per cent. of quartz.

The Wilfley table used for the tests had a net working-surface of 2 ft. by 4 ft. This is the table that has been found very satisfactory for students' work at the Massachusetts Institute of Technology. An error is present to a slight extent in the full-sized table, 16 ft. long by 7 ft. wide, and to a serious ex-

tent in the small Wilfley testing-table, 7 ft. long, found in some of the schools. It is due to tacking tapered riffle-cleats on to a linoleum plane surface, thereby making two planes: first, the roughing-plane over the riffle-cleats, *E*, Fig. 1; second, the cleaning-plane or part where there are no riffles, *F*, Fig. 1. These two planes make an angle with each other, or a slight trough, which heaps up the sands deeper than is wise along the line of the tips of the riffle-cleats. This error is completely overcome on the little table here used by cutting the riffles down into the wooden surface of the table. The roughing- and cleaning-planes are therefore one and the same plane. By observing this precaution I believe that this little table is able to do as good work as the full-sized table.

Comparing the little table with the full-sized table as to areas and capacity, assuming that their capacities are proportional to their areas, we have Table I.

TABLE I.—*Area and Capacity of Small and Large Wilfley Tables.*

	Little Table.		Large Table.	
Area, . . .	8	sq. ft.	112	sq. ft.
Feed, . . .	1	kg. per min.	22	tons per 24 hr.
Feed, . . .	0.75	kg. per min.	16.6	tons per 24 hr.
Feed, . . .	0.5	kg. per min.	11	tons per 24 hr.

These figures represent the usual range used in practice.

Seventeen runs in all were made; Nos. 1 to 5, inclusive, were made upon natural products, the several feed-products being 2 mm. to 0; 1 mm. to 0; 0.5 mm. to 0; 0.25 mm. to 0; and 2 mm. to 0. Run No. 5, although fed with the same size as No. 1, was fed at a different rate. In making these runs no effort was made to re-run the middlings; first, because the concentrates and tailings would both have been contaminated and would not have shown as well; secondly, because the middlings themselves would have undergone a change in composition. In consequence of this ruling, the quantities of middlings appear abnormally large.

In these runs the dividing-line between concentrates and middlings was chosen so as to make concentrates nearly clean to the eye. The dividing-line between middlings and tailings was chosen so as to keep all the large grains of heavy mineral in the middlings. The four products—concentrates, middlings,

tailings and slimes—were sized on a series of sieves, and the quartz in them determined by dissolving out the galena in hydrochloric acid. The galena was determined by difference.

Runs Nos. 6 to 11, inclusive, were all upon sized products, and the results obtained are given in Table II.

TABLE II.—*Sizes and Weights of Materials Fed to Table.*  
*Tests Nos. 6 to 11.*

Run Number.	Sieves Diameter.		Actual Weights Fed. kg.
	Through. mm.	On. mm.	
6	2	1.4	12.15
7	1.4	1.0	6.74
8	1	0.75	4.93
9	0.75	0.50	2.85
10	0.50	0.36	1.70
11	0.36	0.28	1.55
	0.28	0.00	3.08
			<hr/> 33.00

The total quantity weighed 33 kg., of which 30 kg. was quartz and 3 kg. was galena. The guiding was done simply to make clean concentrates and tailings. The middlings were in every case re-run until they could not be further reduced without contaminating the concentrates or the tailings. Where a sized ore is free from included grains and from any middle-weight mineral, the feeding-back of the middlings on the same table is logically good practice, because the middlings product is simply a mixture of concentrates and tailings on a large scale run; therefore, they could be fed back on the same table and disappear entirely without harm to concentrates or tailings.

Runs Nos. 12 to 17, inclusive, were made upon sorted or classified products. The classifier, Fig. 2, had 12 closed spigots or blind spigots; that is to say, spigots which discharged sand into 2-gal. bottles as fast as it came, but discharged no water. The sorting-columns were of 0.5-in. pipe, squared at the top and 3 in. long. Expressed in mm. per second, the rising-currents in the successive sorting-columns were: 105, 85, 69, 55, 45, 36, 29, 23, 19, 15, 12, 10, respectively. The 13th spigot had no rising-current, and it was simply a safety spigot to prevent any accumulation of sand that was too light to go down in the 12th and too heavy to go over into the overflow. This apparatus gives a set of products beautifully classified.



TABLE III.—Distribution of Quartz and Galena in Runs Nos. 12 to 17.

Run No.....	12				13				14				
No. of Spigot.....	1				2				3				
Actual Weight in kg..	15.110				15.775				11.175				
Rising Current, mm. per sec.....	105.				85.				69.				
Through mm.	On mm.	Quartz.	Galena.	Mid-dlings.	Quartz.	Galena.	Mid-dlings.	Quartz.	Galena.	Mid-dlings.	Quartz.	Galena.	Mid-dlings.
2.83	2.49	0.052	0.004	0.007	1.517	.....	.....	0.213	.....	.....	.....	.....	.....
2.49	2.06	2.408	0.709	0.021	20.299	.....	0.006	3.617	.....	0.003	0.112	.....	.....
2.06	1.63	17.170	7.216	0.085	20.805	0.004	0.009	6.510	0.002	0.003	0.394	.....	.....
1.63	1.44	9.885	7.650	0.112	19.856	0.003	0.013	12.635	0.003	0.004	1.210	.....	.....
1.44	1.27	9.381	8.476	0.118	15.746	0.004	0.016	14.249	0.002	0.002	3.475	0.001	0.001
1.27	1.10	2.480	3.391	0.010	15.746	0.004	0.016	14.249	0.002	0.002	3.475	0.001	0.001
1.10	0.97	1.945	3.742	0.022	5.161	0.006	0.011	14.339	0.003	0.001	2.573	.....	.....
0.97	0.84	2.041	5.435	0.025	5.925	0.037	0.023	15.208	0.027	.....	9.530	0.006	.....
0.84	0.68	0.861	3.914	0.020	2.734	0.063	0.017	10.646	0.018	.....	12.783	0.008	.....
0.68	0.57	0.535	3.479	0.009	1.527	0.147	0.013	7.499	0.030	.....	20.128	0.037	.....
0.57	0.45	0.356	4.143	.....	1.558	0.865	.....	8.795	0.167	.....	26.312	0.056	.....
0.45	0.36	0.100	1.634	.....	0.217	0.678	.....	1.437	0.203	.....	9.741	0.070	.....
0.36	0.28	0.068	1.407	.....	0.107	1.215	.....	0.942	0.678	.....	6.502	0.275	.....
0.28	0.24	0.022	0.457	.....	0.028	0.517	.....	0.190	0.455	.....	1.638	0.489	.....
0.24	0.20	0.016	0.258	.....	0.015	0.414	.....	0.124	0.825	.....	0.667	0.892	.....
0.20	0.15	0.010	0.145	.....	0.009	0.233	.....	0.045	0.594	.....	0.223	1.107	.....
0.15	0.12	0.007	0.089	.....	0.005	0.107	.....	0.013	0.295	.....	0.068	0.715	.....
0.12	0.10	0.001	0.018	.....	0.003	0.025	.....	0.007	0.093	.....	0.037	0.458	.....
0.10	0.08	0.007	0.037	.....	0.005	0.029	.....	0.010	0.102	.....	0.025	0.301	.....
0.08	0.00	0.007	0.057	.....	0.009	0.023	.....	0.080	0.050	.....	0.012	0.132	.....
Total.....		47.352	52.261	0.429	95.526	4.370	0.108	96.569	3.587	0.013	95.440	4.546	0.002
Settling-ratio.....		1.58			4.11			3.93			3.26		

TABLE III.—Continued.

[illegible]

To define the classified products more completely, a small aliquot part of each was sized, photographed and analyzed. The photograph, Fig. 8, shows to the eye the distribution of sizes in each spigot: Table III. shows the distribution of quartz and galena in the different sizes of each spigot. Expressed in mm., the sieve-sizes used were: 2.83, 2.49, 2.06, 1.63, 1.44, 1.27, 1.10, 0.97, 0.84, 0.68, 0.57, 0.45, 0.36, 0.28, 0.24, 0.20, 0.15, 0.12, 0.10, 0.08. The middlings picked out and weighed for the first four spigots consisted of blende and galena included

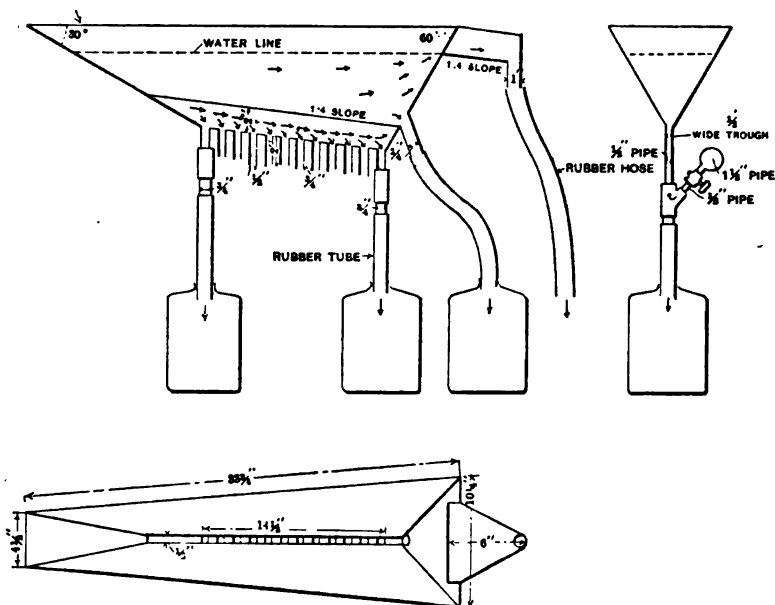


FIG. 2.—CLASSIFIER USED FOR RUNS NOS. 12 TO 17.

grains, with some free blende-grains. Their use here is simply to show how nearly pure the galena was. The settling-ratios are of special interest; for example, at the foot of spigot No. 4 we have the settling-ratio, 3.26, which signifies that in spigot No. 4 the average diameter of the quartz-grains is 3.26 times the average diameter of the galena-grains. The method of computing these ratios is given in my paper, *Close Sizing Before Jigging*.<sup>1</sup> It was thought wiser to combine the spigots

<sup>1</sup> *Trans.*, xxiv., 449, 450 (1894).

somewhat instead of making 12 separate runs; accordingly, the 6 runs were fed with products as follows: 1st spigot; 2d spigot; 3d and 4th together; 5th and 6th together; 7th, 8th and 9th together; 10th, 11th and 12th together.

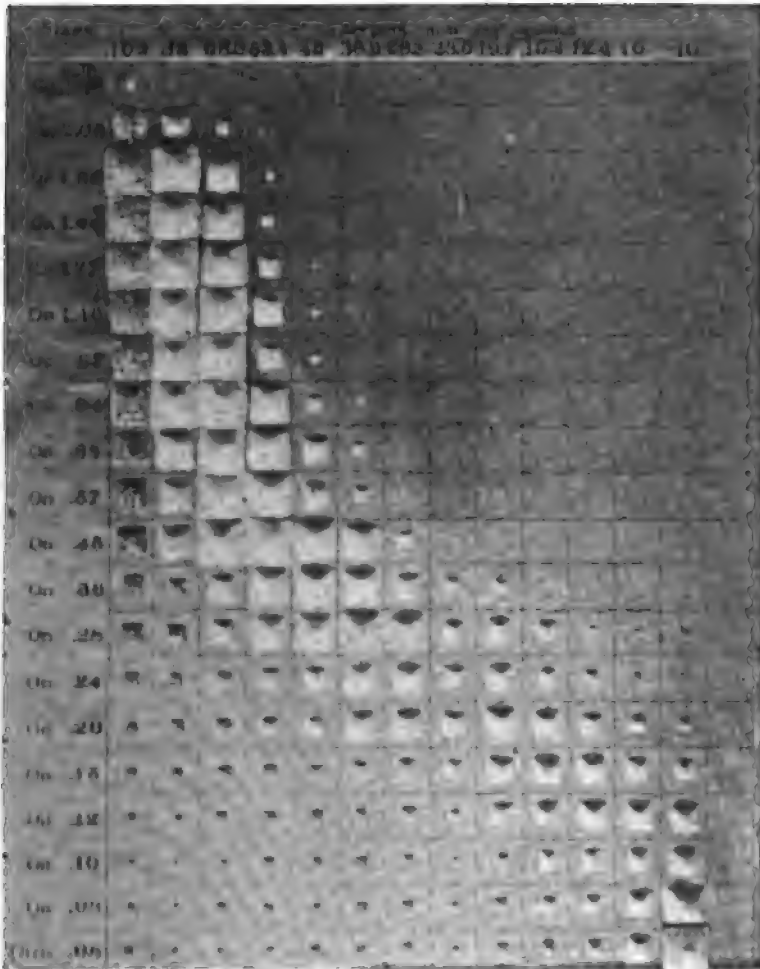


FIG. 3.—DISTRIBUTION OF SIZES BY THE CLASSIFIER.

The first 5 runs on natural products computed on the basis of a 100-ton lot, and to the rate of feeding of a full-sized table, gave products shown in Table IV.

TABLE IV.—*Results of Runs Nos. 1 to 5.*

	Run No. 1.	Run No. 2.	Run No. 3.	Run No. 4.	Run No. 5.
Size of Feed.	mm. 2 to 0.	mm. 1 to 0.	mm. 0.5 to 0.	mm. 0.25 to 0.	mm. 2 to 0.
Rate of feed per 24 hours, .	Tons. 22.	Tons. 22.	Tons. 11.	Tons. 11.	Tons. 11.
Concentrates, . . . .	4.114	2.973	4.667	5.943	2.808
Middlings, . . . .	21.486	20.750	25.981	21.028	45.538
Tailings, . . . .	72.856	72.903	62.813	60.487	50.688
Slimes, . . . .	1.544	3.374	6.539	13.142	0.966
Total, . . . .	100.000	100.000	100.000	100.000	100.000

The next 6 runs on sized products, computed on the basis of a 100-ton lot, and to the rate of feeding of a full-sized table, gave products shown in Table V.

TABLE V.—*Results of Runs Nos. 6 to 11.*

	Run No. 6.	Run No. 7.	Run No. 8.	Run No. 9.	Run No. 10.	Run No. 11.
Size of Feed, . . . .	mm. 2.00 to 1.4	mm. 1.4 to 1.0	mm. 1.0 to 0.75	mm. 0.75 to 0.50	mm. 0.50 to 0.36	mm. 0.36 to 0.28
Rate of feed per 24 hours, . . . .	Tons. 22.	Tons. 16.6	Tons. 11.	Tons. 11.	Tons. 11.	Tons. 11.
Concentrates, . . . .	6.537	9.728	12.064	13.168	12.171	15.137
Middlings, . . . .	1.647	1.901	1.694	1.602	5.310	3.170
Tailings, . . . .	91.816	88.371	86.242	85.230	82.519	81.693
Slimes, . . . .	0.000	0.000	0.000	0.000	0.000	0.000
Total, . . . .	100.000	100.000	100.000	100.000	100.000	100.000

The last 6 runs, computed on the basis of 100-ton lots, and to the rate of feeding of a full-sized table, gave products shown in Table VI.

TABLE VI.—*Results of Runs Nos. 12 to 17 Computed to Full-Sized Table.*

	Run No. 12.	Run No. 13.	Run No. 14.	Run No. 15.	Run No. 16.	Run No. 17.
Classifier spigots, num- bers that were fed, .	1.	2.	3, 4.	5, 6.	7, 8, 9.	10, 11, 12.
Classifier currents mm. per second through which grains settled,	105.	85.	55.4	36.3	19.1	10.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Rate of feed to Wil- fley, 24 hours, .	11.	11.	16.6	11.	11.	11.
Concentrates, . . . .	49.649	3.950	3.398	4.940	5.7165	4.980
Middlings, . . . .	5.534	1.307	0.663	0.828	1.0435	4.262
Tailings, . . . .	44.817	94.743	95.939	94.232	93.240	90.758
Slimes, . . . .	0.000	0.000	0.000	0.000	0.000	0.000
Total, . . . .	100.000	100.000	100.000	100.000	100.000	100.000

Comparing the 17 runs as to quantity of the products without looking at the quality, it will be noticed at once that the concentrates and tailings in runs Nos. 6 to 11 and Nos. 12 to 17 are very much larger in quantity than these products in runs Nos. 1 to 5; while the middlings are very much smaller in quantity.

A comprehensive table of all 17 runs is given in Table VII., which shows the proportions of concentrates, middlings, tailings and slimes in each, and also the percentage of galena and quartz in the various products.

Tables VIII., IX., X. and XI. give the weights in tons of the different sizes, and also the proportion of quartz and galena in each product by sizes.

In comparing the analyses of the concentrates of these five runs (Table VIII.), we see a very remarkable similarity in the behavior of the quartz and galena through all five runs. The coarser sizes and the finer sizes are almost clean galena, being nearly free from quartz. At a point somewhere a little below the middle, the quartz rises to a maximum, which in the first run reaches 18.99 per cent. of quartz, in the third run reaches 7.38 per cent. of quartz, and in the fifth run reaches 13.80 per cent. of quartz.

Comparing the different analyses of the middlings, Table IX., we find the galena among the very largest and smallest grains gives a very high percentage, and down to a little below the middle the galena runs down to a very low percentage, while the quartz behaves just in the opposite way. This is analogous to the composition of the concentrates.

Comparing the tailings of the five runs, Table X., we note that the galena appears only to a very slight degree in any of the tailings until we get down to the smaller sizes, and there we have figures that rise to an almost alarming size, the first run giving 17.5 per cent. of galena in the finest size; the 2d, 17.8 per cent.; the 5th run giving 12.17 per cent. in the finest size.

The slimes, Table XI., which have a serious quantity of material only in the finest size, have also a serious percentage of lead in that finest size. The other percentages of lead are generally much smaller. There are three exceptions, in the 2d, 3d and 4th runs, where the percentages run high in the larger

TABLE VII.—Summary of Results of Runs Nos. 1 to 17.

No. of Run.	Size.	Rate of Feeding.		Composition of the Feed.				Percentage of the Products.				Composition of Products.								Per Cent. of Total Galena.				Total Quantity Fed.
		Kgs. Per Min.	Tons 24 Hr.	Quartz.		Galena.	Concen- trates.	Mid- dlings.	Tail- ings.	Slimes.	Concentrates.		Middlings.		Tailings.		Slimes.		Concen- trates.	Mid- dlings.	Tail- ings.	Slimes.		
				Per Ct.	Galena.						Per Ct.	Galena.	Per Ct.	Galena.	Per Ct.	Galena.	Per Ct.	Galena.					Per Ct.	
1	2 to 0	1	22	90.91	9.09	4.11	21.48	72.87	1.54	9.92	90.08	76.42	23.58	99.49	0.51	81.10	18.90	39.20	53.34	3.82	3.64	11		
2	1 to 0	1	22	90.91	9.09	2.97	20.75	72.91	3.37	8.50	91.50	73.37	26.63	99.39	0.61	90.29	9.71	34.58	57.34	4.72	3.36	11		
3	0.5 to 0	0.5	11	90.91	9.09	4.67	25.98	62.81	6.54	2.40	97.60	84.10	15.90	99.10	0.90	87.82	12.18	44.86	41.98	5.44	7.72	11		
4	0.25 to 0	0.5	11	90.91	9.09	5.34	21.03	60.49	13.14	2.27	97.73	87.16	12.84	98.39	1.61	90.04	9.96	51.48	27.59	8.20	12.73	11		
5	2 to 0	0.5	11	90.91	9.09	2.80	45.67	50.30	1.23	4.66	95.34	86.29	13.71	98.71	0.29	85.38	14.62	29.06	67.79	1.62	1.53	9.63		
6	2 to 1.4	1	22	92.60	7.40	6.54	1.65	91.81	.....	0.77	99.23	40.33	59.67	99.96	0.04	.....	.....	87.43	12.05	0.52	.....	12.08		
7	1.4 to 1	0.75	16.6	89.08	10.92	9.73	1.90	88.37	.....	0.77	99.23	76.90	23.10	100.00	0.00	.....	.....	96.43	3.57	0.00	.....	6.74		
8	1 to 0.75	0.5	11	87.32	12.68	12.06	1.69	86.25	.....	0.99	99.01	83.00	17.00	99.91	0.09	.....	.....	97.62	1.80	0.58	.....	4.93		
9	0.75 to 0.5	0.5	11	87.15	12.85	13.15	1.60	85.25	.....	2.50	97.50	77.40	22.60	99.65	0.35	.....	.....	96.58	2.29	1.13	.....	2.845		
10	0.5 to 0.36	0.5	11	85.92	14.08	12.18	5.31	82.51	.....	0.69	99.31	80.03	19.97	99.76	0.24	.....	.....	90.57	7.95	1.48	.....	1.72		
11	0.36 to 0.28	0.5	11	85.70	14.30	15.10	3.17	81.73	.....	2.14	97.86	84.67	15.35	99.56	0.44	.....	.....	94.60	3.10	2.30	.....	1.59		
Classifier.																								
12	1st spigot	0.5	11	49.82	50.18	49.65	5.53	44.82	.....	0.74	99.26	86.15	13.85	99.71	0.29	.....	.....	98.21	1.53	0.26	.....	13.60		
13	2d "	0.5	11	95.21	4.79	3.95	1.31	94.74	.....	1.38	98.62	66.05	33.95	99.64	0.36	.....	.....	81.35	10.72	7.93	.....	14.197		
14	3 and 4 "	0.75	16.6	96.23	3.77	3.40	0.66	95.94	.....	1.15	98.85	65.57	34.43	99.80	0.20	.....	.....	88.95	5.98	5.07	.....	14.629		
15	5 and 6 "	0.5	11	94.39	5.61	4.94	0.83	94.23	.....	1.65	98.35	71.10	28.90	99.45	0.55	.....	.....	86.66	4.29	9.05	.....	3.745		
16	7, 8, 9 "	0.5	11	93.74	6.26	5.72	1.04	93.24	.....	1.16	98.84	83.75	16.25	99.54	0.46	.....	.....	90.58	2.90	6.52	.....	2.28		
17	10, 11, 12 "	0.5	11	93.73	6.27	4.98	4.26	90.76	.....	0.38	99.62	83.72	16.28	99.34	0.66	.....	.....	79.33	10.69	9.93	.....	1.9		

TABLE VIII.—*Proportion of Quartz and Galena in Products.*

NOTE.—Concentrates sized and weighed. The weights are computed in tons and fractions of a ton on the 100-ton basis.

Sizes.		Run No. 1.	Run No. 2.	Run No. 3.	Run No. 4.	Run No. 5.
Through.	On.					
mm.	mm.	Ton.	Ton.	Ton.	Ton.	Ton.
.....	2.06	0.017	.....	.....	.....	0.009
2.06	1.63	0.059	.....	.....	.....	0.037
1.63	1.44	0.066	.....	.....	.....	0.054
1.44	1.27	0.112	.....	.....	.....	0.076
1.27	1.10	0.084	.....	.....	.....	0.049
1.10	0.97	0.120	0.003	.....	.....	0.079
0.97	0.84	0.174	0.012	.....	.....	0.104
0.84	0.68	0.206	0.027	.....	.....	0.128
0.68	0.57	0.245	0.048	.....	.....	0.138
0.57	0.45	0.506	0.280	0.225	.....	0.288
0.45	0.36	0.402	0.141	0.322	.....	0.201
0.36	0.28	0.445	0.465	1.000	0.227	0.303
0.28	0.24	0.306	0.304	0.386	0.081	0.179
0.24	0.20	0.375	0.370	0.586	0.760	0.230
0.20	0.15	0.307	0.324	0.483	0.997	0.218
0.15	0.12	0.209	0.313	0.483	0.968	0.213
0.12	0.10	0.110	0.207	0.271	0.397	0.082
0.10	0.08	0.189	0.235	0.404	0.871	0.229
0.08	0.00	0.182	0.244	0.507	1.052	0.191
Total tons.....		4.114	2.973	4.667	5.343	2.808

Analyses of the above products giving percentages of galena (PbS) and quartz (SiO<sub>2</sub>).

Sizes.		Run No. 1.		Run No. 2.		Run No. 3.		Run No. 4.		Run No. 5.	
Thro.	On.	Galena.	Quartz.	Galena.	Quartz.	Galena.	Quartz.	Galena.	Quartz.	Galena.	Quartz.
mm.	mm.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.
.....	2.06	100.00	0.00	.....	.....	.....	.....	.....	.....	100.00	0.00
2.06	1.63	99.77	0.23	.....	.....	.....	.....	.....	.....	97.56	2.44
1.63	1.44	99.80	0.20	.....	.....	.....	.....	.....	.....	100.00	0.00
1.44	1.27	99.88	0.12	.....	.....	.....	.....	.....	.....	99.87	0.13
1.27	1.10	99.76	0.24	.....	.....	.....	.....	.....	.....	99.29	0.71
1.10	0.97	99.43	0.57	100.00	0.00	.....	.....	.....	.....	99.28	0.72
0.97	0.84	98.42	1.58	99.72	0.28	.....	.....	.....	.....	99.80	0.20
0.84	0.68	96.54	3.46	99.90	0.10	.....	.....	.....	.....	99.55	0.45
0.68	0.57	94.47	5.53	100.00	0.00	.....	.....	.....	.....	99.52	0.48
0.57	0.45	91.05	8.95	100.00	0.00	99.61	0.39	.....	.....	97.67	2.33
0.45	0.36	83.81	16.19	99.81	0.19	99.71	0.29	.....	.....	93.34	6.66
0.36	0.28	81.24	18.76	99.74	0.26	99.48	0.52	96.56	3.44	89.24	10.76
0.28	0.24	81.01	18.99	99.16	0.84	99.36	0.64	96.67	3.33	86.20	13.80
0.24	0.20	84.39	15.61	98.25	1.75	97.81	2.19	99.24	0.76	88.21	11.79
0.20	0.15	89.48	10.52	98.02	1.98	93.14	6.86	98.54	1.46	92.92	7.08
0.15	0.12	95.08	4.92	98.78	1.22	92.62	7.38	96.84	3.16	97.52	2.48
0.12	0.10	95.08	4.92	99.32	0.68	95.35	4.65	95.54	4.46	99.03	0.97
0.10	0.08	97.74	2.26	99.57	0.43	98.71	1.29	96.66	3.34	99.65	0.35
0.08	0.00	99.45	0.55	99.62	0.38	99.40	0.60	98.72	1.28	99.63	0.37
Total con- centrates. }		90.08	9.92	91.50	8.50	97.60	2.40	97.73	2.27	95.34	4.66



TABLE IX.—*Proportion of Quartz and Galena in Products.*

NOTE.—Middlings sized and weighed and the weights computed in tons and fractions of a ton on the 100-ton basis.

Size. On.	Run No. 1.	Run No. 2.	Run No. 3.	Run No. 4.	Run No. 5.
mm.					
2.06	0.132	.....	.....	.....	0.206
1.63	0.795	.....	.....	.....	1.595
1.44	0.783	.....	.....	.....	2.134
1.27	1.202	.....	.....	.....	2.986
1.10	0.954	.....	.....	.....	2.438
0.97	1.056	0.292	.....	.....	3.178
0.84	1.552	1.330	.....	.....	4.793
0.68	2.021	0.329	.....	.....	5.113
0.57	1.865	1.350	.....	.....	4.323
0.45	3.112	3.203	2.171	.....	8.871
0.36	2.326	2.680	3.117	.....	3.144
0.28	2.526	3.945	5.955	0.402	3.655
0.24	0.848	1.436	4.805	1.684	1.079
0.20	1.230	2.932	3.698	4.729	0.969
0.15	0.648	1.551	4.362	4.713	0.581
0.12	0.207	0.893	0.481	3.660	0.223
0.10	0.075	0.299	0.418	2.296	0.050
0.08	0.061	0.286	0.601	2.216	0.054
0.00	0.093	0.224	0.373	1.328	0.146
Total tons....	21.486	20.750	25.981	21.028	45.538

Analyses of the above products giving percentages of galena (PbS) and quartz (SiO<sub>2</sub>).

Size.	Run No. 1.		Run No. 2.		Run No. 3.		Run No. 4.		Run No. 5.	
On.	Galena.	Quartz.	Galena.	Quartz.	Galena.	Quartz.	Galena.	Quartz.	Galena.	Quartz.
mm.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.
2.06	73.47	26.53	.....	.....	.....	.....	.....	.....	38.43	61.57
1.63	75.39	24.61	.....	.....	.....	.....	.....	.....	41.68	58.32
1.44	69.47	30.53	.....	.....	.....	.....	.....	.....	30.21	69.79
1.27	62.80	37.20	.....	.....	.....	.....	.....	.....	22.69	77.31
1.10	54.75	45.25	.....	.....	.....	.....	.....	.....	18.04	81.96
0.97	43.80	56.20	90.46	9.54	.....	.....	.....	.....	13.85	86.15
0.84	31.40	68.60	89.46	10.54	.....	.....	.....	.....	11.43	88.57
0.68	20.10	79.90	81.60	18.40	.....	.....	.....	.....	9.92	90.08
0.57	16.70	83.30	69.23	30.77	.....	.....	.....	.....	9.60	90.40
0.45	11.30	88.70	37.50	62.50	66.66	33.34	.....	.....	9.07	90.93
0.36	8.11	91.89	20.22	79.78	23.67	76.33	.....	.....	8.40	91.60
0.28	6.44	93.56	12.81	87.19	14.10	85.90	29.43	70.57	8.36	91.64
0.24	4.92	95.08	8.41	91.59	6.60	93.40	19.74	80.26	7.75	92.25
0.20	3.68	96.32	7.26	92.74	5.16	94.84	11.78	88.22	8.27	91.73
0.15	4.44	95.56	5.36	94.64	5.01	94.99	8.25	91.75	10.20	89.80
0.12	6.65	93.35	4.49	95.51	6.56	93.44	7.10	92.90	17.39	82.61
0.10	7.26	92.74	7.45	92.55	6.46	93.54	6.81	93.19	26.88	73.12
0.08	32.23	67.77	11.72	88.28	10.24	89.76	9.22	90.78	58.90	41.10
0.00	90.46	9.54	48.33	51.67	70.76	29.24	51.84	48.16	90.87	9.13
Total midd.	23.58	76.42	26.63	73.37	15.90	84.10	12.84	87.16	13.71	86.29

TABLE X.—*Proportion of Quartz and Galena in Products.*

NOTE.—Tailings sized and weighed and the weights computed in tons and fractions of a ton on the 100-ton basis.

Size. On.	Run No. 1.	Run No. 2.	Run No. 3.	Run No. 4.	Run No. 5.
mm.					
2.06	3.777	.....	.....	.....	2.003
1.63	14.713	.....	.....	.....	11.883
1.44	11.145	.....	.....	.....	9.065
1.27	8.085	.....	.....	.....	10.600
1.10	6.174	.....	.....	.....	4.294
0.97	7.322	11.860	.....	.....	4.452
0.84	5.191	16.217	.....	.....	1.489
0.68	3.350	8.821	.....	.....	0.682
0.57	2.078	5.789	.....	.....	0.405
0.45	2.501	11.639	20.635	.....	0.396
0.36	1.581	4.167	11.120	.....	0.162
0.28	1.056	3.315	10.790	0.400	0.456
0.24	0.523	0.915	2.829	2.019	0.303
0.20	0.633	2.341	3.277	12.345	0.680
0.15	0.739	1.860	3.574	11.948	1.075
0.12	1.139	1.781	4.308	9.015	0.507
0.10	0.624	1.067	1.113	6.118	0.614
0.08	0.948	1.461	2.965	9.778	0.878
0.00	1.277	1.670	2.202	8.864	0.742
Total tons....	72.856	72.903	62.813	60.487	50.686

Analyses of the above products giving percentages of galena (PbS) and quartz (SiO<sub>2</sub>).

Size. On.	Run No. 1.		Run No. 2.		Run No. 3.		Run No. 4.		Run No. 5.	
	Galena.	Quartz.	Galena.	Quartz.	Galena.	Quartz.	Galena.	Quartz.	Galena.	Quartz.
mm.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.
2.06	0.40	99.60	.....	.....	.....	.....	.....	.....	0.00	100.00
1.63	0.40	99.60	.....	.....	.....	.....	.....	.....	0.00	100.00
1.44	0.50	99.50	.....	.....	.....	.....	.....	.....	0.00	100.00
1.27	0.20	99.80	.....	.....	.....	.....	.....	.....	0.05	99.95
1.10	0.01	99.99	.....	.....	.....	.....	.....	.....	0.02	99.98
0.97	0.02	99.98	0.02	99.98	.....	.....	.....	.....	0.02	99.98
0.84	0.00	100.00	0.01	99.99	.....	.....	.....	.....	0.03	99.97
0.68	0.00	100.00	0.00	100.00	.....	.....	.....	.....	0.01	99.99
0.57	0.00	100.00	0.00	100.00	.....	.....	.....	.....	0.08	99.92
0.45	0.00	100.00	0.00	100.00	0.00	100.00	.....	.....	0.05	99.95
0.36	0.08	99.92	0.12	99.88	0.16	99.84	.....	.....	0.68	99.32
0.28	0.12	99.88	0.16	99.84	0.64	99.36	2.95	97.05	0.80	99.20
0.24	0.69	99.31	0.26	99.74	2.03	97.97	0.41	99.59	0.74	99.26
0.20	1.24	98.76	0.80	99.20	1.19	98.81	0.69	99.31	0.82	99.18
0.15	1.45	98.55	1.40	98.60	1.49	98.51	1.00	99.00	0.76	99.24
0.12	1.82	98.18	1.89	98.11	1.65	98.35	1.26	98.74	1.16	98.84
0.10	2.88	97.12	1.69	98.31	1.60	98.40	1.76	98.24	1.71	98.29
0.08	3.43	96.57	2.60	97.40	1.51	98.49	1.49	98.51	3.00	97.00
0.00	17.50	82.50	17.85	82.15	8.55	91.45	4.28	95.72	12.17	87.83
Total tailin's	0.51	99.49	0.61	99.39	0.90	99.10	1.61	98.39	0.29	99.71

sizes, but the quantity is so small that these losses are insignificant.

TABLE XI.—*Proportion of Quartz and Galena in Products.*

NOTE.—Slimes sized and weighed. The weights are computed in tons and parts of a ton, on the 100-ton basis.

Sizes.		Run No. 1.	Run No. 2.	Run No. 3.	Run No. 4.	Run No. 5.
Through.	On.					
mm.	mm.					
0.45	0.36	0.156	.....	.....	.....	.....
0.36	0.28	0.047	.....	.....	0.214	0.003
0.28	0.24	0.036	.....	.....	0.026	0.004
0.24	0.20	0.053	0.032	.....	0.044	0.007
0.20	0.15	0.063	0.072	0.207	0.091	0.027
0.15	0.12	0.052	0.062	0.078	0.138	0.037
0.12	0.10	0.068	0.149	0.241	1.515	0.038
0.10	0.08	0.134	0.446	1.662	1.268	0.244
0.08	0.00	0.935	2.613	4.351	9.846	0.606
Total tons.....		1.544	3.374	6.539	13.142	0.966

Analyses of the above products giving percentages of galena (PbS) and quartz (SiO<sub>2</sub>).

Sizes.		Run No. 1.		Run No. 2.		Run No. 3.		Run No. 4.		Run No. 5.	
Thro.	On.	Galena.	Quartz.	Galena.	Quartz.	Galena.	Quartz.	Galena.	Quartz.	Galena.	Quartz.
mm.	mm.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.
0.45	0.36	0.00	100.00	.....	.....	.....	.....	.....	.....	.....	.....
0.36	0.28	10.20	89.80	.....	.....	.....	.....	48.54	51.46	18.30	81.70
0.28	0.24	10.00	90.00	.....	.....	.....	.....	54.55	45.45	15.40	84.60
0.24	0.20	10.81	89.19	14.04	85.96	.....	.....	40.22	59.78	11.80	88.20
0.20	0.15	12.58	87.42	7.94	92.06	45.21	54.79	37.16	62.84	8.10	91.90
0.15	0.12	19.00	81.00	7.26	92.74	21.21	78.79	28.96	71.04	6.50	93.50
0.12	0.10	24.28	75.72	7.19	92.81	17.53	82.47	9.37	90.63	5.00	95.00
0.10	0.08	27.04	72.96	5.03	94.97	8.53	91.47	6.87	93.13	6.40	93.60
0.08	0.00	28.31	71.69	10.72	89.28	11.53	88.47	8.76	91.24	19.40	80.60
Total slimes...		18.90	81.10	9.71	90.29	12.18	87.82	9.96	90.04	14.62	85.38

Commenting upon runs Nos. 6 to 11, Table XII., as compared with runs Nos. 1 to 5, we note immediately that the concentrates all the way through are almost pure galena with scarcely any quartz, and the tailings are almost pure quartz and scarcely any galena. The middlings, as remarked before, are so small in quantity that they affect the runs but little, and when we consider that they can go directly back on to the table in the continuous run, they do not affect the result at all. This set of runs, Nos. 6 to 11, therefore appears to distance runs Nos. 1 to 5 in the competition. There is really no comparison, since runs Nos. 1 to 5 are not in the same class with them.

TABLE XII.—*Results of Runs Nos. 6 to 11 Computed to Full Size.*

NOTE.—The weights of products have been computed in tons and fractions thereof.

	Run No. 6.	Run No. 7.	Run No. 8.	Run No. 9.	Run No. 10.	Run No. 11.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Concentrates.....	6.537	9.728	12.064	13.168	12.171	15.137
Middlings.....	1.647	1.901	1.694	1.602	5.310	3.170
Tailings.....	91.816	88.371	86.242	85.230	82.519	81.693
Slimes.....	0.000	0.000	0.000	0.000	0.000	0.000
Total.....	100.000	100.000	100.000	100.000	100.000	100.000

Analyses of the above products giving percentages of galena (PbS) and quartz (SiO<sub>2</sub>).

	Run No. 6.		Run No. 7.		Run No. 8.		Run No. 9.		Run No. 10.		Run No. 11.	
	Galena.	Quartz.	Galena.	Quartz.	Galena.	Quartz.	Galena.	Quartz.	Galena.	Quartz.	Galena.	Quartz.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Concentrates.....	99.23	0.77	99.23	0.77	99.01	0.99	97.50	2.50	99.31	0.69	97.86	2.14
Middlings.....	59.67	40.33	23.10	76.90	17.00	83.00	22.60	77.40	19.97	80.03	15.35	84.65
Tailings.....	0.04	99.96	0.00	100.00	0.09	99.91	0.35	99.65	0.24	99.76	0.44	99.56
Slimes.....												

Comparing the concentrates of runs Nos. 12 to 17, Table XIII., we see in the first place an enormous heaping-up of concentrates in run No. 12. The weight, 49 tons, is more than double the weight of all the other five runs in this set put together. This heaping-up of the great quantity of concentrates on the table which treats the first spigot of a classifier is one of the prominent features of the use of a classifier in preparation for feeding Wilfley tables. If we look at the total percentage of galena and quartz in the concentrates of run No. 12 we see that they contain 99.26 per cent. of galena and 0.74 per cent. of quartz. This makes an extremely good showing, and one which bids for favorable consideration of the classifier set.

Looking at the later spigots, that is to say, runs Nos. 13 to 17, inclusive, in the analyses, we see that the percentage of quartz looks high in the coarser sizes. This would seem a serious disadvantage if it were not for the fact that these products which have the high percentages of quartz are so small in quantity that the quartz cuts scarcely any figure in the final percentage of quartz in the concentrates. Altogether this set

TABLE XIII.—*Results of Runs Nos. 12 to 17 Computed to Full Size.*

NOTE.—The concentrates have been sized and weighed and the weights computed in tons and fractions thereof on the 100-ton basis.

Sizes.		Run No. 12.	Run No. 13.	Run No. 14.	Run No. 15.	Run No. 16.	Run No. 17.
Through.	On.						
mm.	mm.						
2.06	2.06	0.128					
1.63	1.63	4.869	0.001	0.0003			
1.44	1.44	6.331	0.001	0.0003			
1.27	1.27	7.861	0.002	0.0003			
1.10	1.10	4.455	0.002	0.0002	0.0005		
0.96	0.96	4.093	0.002	0.0003	0.0003		
0.84	0.84	5.837	0.011	0.001	0.0003	0.0005	
0.68	0.68	3.674	0.036	0.002	0.0005	0.0005	0.0004
0.57	0.57	3.615	0.124	0.006	0.001	0.001	0.0004
0.45	0.45	4.347	0.730	0.054	0.005	0.004	0.0023
0.36	0.36	2.063	1.208	0.174	0.012	0.007	0.004
0.28	0.28	1.232	0.687	0.656	0.060	0.049	0.015
0.24	0.24	0.445	0.384	0.415	0.110	0.077	0.015
0.20	0.20	0.330	0.393	0.697	0.332	0.138	0.057
0.15	0.15	0.152	0.223	0.701	1.176	0.220	0.108
0.12	0.12	0.088	0.084	0.393	1.321	0.634	0.086
0.10	0.10	0.029	0.021	0.143	0.551	0.748	0.109
0.08	0.08	0.055	0.029	0.104	1.057	2.300	0.934
0.00	0.00	0.045	0.012	0.052	0.315	1.539	3.650
Total tons.....		49.649	3.950	3.398	4.940	5.717	4.980

Analyses of the above products giving percentages of galena (PbS) and quartz (SiO<sub>2</sub>).

Size.	Run No. 12.		Run No. 13.		Run No. 14.		Run No. 15.		Run No. 16.		Run No. 17.	
	Galena.	Quartz.	Galena.	Quartz.	Galena.	Quartz.	Galena.	Quartz.	Galena.	Quartz.	Galena.	Quartz.
mm.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.
2.06	100.00	0.00										
1.63	99.96	0.04	100.00	0.00	60.00	40.00						
1.44	99.96	0.04	100.00	0.00	75.00	25.00						
1.27	99.95	0.05	93.10	6.90	75.00	25.00						
1.10	99.84	0.16	91.45	8.55	85.71	14.29	0.00	100.00				
0.96	99.69	0.31	89.69	10.31	80.00	20.00	87.50	12.50				
0.84	99.45	0.55	95.63	4.37	98.13	1.87	85.72	14.28	0.00	100.00		
0.68	99.03	0.97	96.15	3.85	97.58	2.42	50.00	50.00	63.63	36.37	50.00	50.00
0.57	98.76	1.24	97.49	2.51	97.75	2.25	50.00	50.00	88.24	11.76	33.33	66.67
0.45	97.80	2.20	98.01	1.99	96.06	3.94	73.36	26.64	88.78	11.22	93.80	6.20
0.36	97.05	2.95	98.80	1.20	96.58	3.42	20.50	79.50	92.53	7.47	96.52	3.48
0.28	96.96	3.04	98.24	1.76	98.02	1.98	95.84	4.16	93.54	6.46	98.20	1.80
0.24	96.85	3.15	98.96	1.04	98.57	1.43	97.46	2.54	97.44	2.56	98.58	1.42
0.20	97.51	2.49	99.35	0.65	99.05	0.95	98.93	1.07	96.37	3.63	99.36	0.64
0.15	97.51	2.49	99.58	0.42	99.42	0.58	99.46	0.54	96.41	3.59	99.19	0.81
0.12	98.88	1.12	99.81	0.19	99.80	0.20	99.76	0.24	97.14	2.86	97.56	2.44
0.10	97.77	2.23	99.82	0.18	99.88	0.12	99.83	0.17	98.37	1.63	96.92	3.08
0.08	97.71	2.29	99.83	0.17	99.86	0.14	99.86	0.14	99.31	0.69	99.30	0.70
0.00	96.86	3.14	99.64	0.36	99.88	0.12	99.84	0.16	99.84	0.16	99.86	0.14
Total concent'.	99.26	0.74	98.62	1.38	98.85	1.15	98.35	1.65	98.84	1.16	99.62	0.38

TABLE XIV.—*Results of Runs Nos. 12 to 17 Computed to Full Size.*

NOTE.—The middlings have been sized and weighed and the weights computed in tons and fractions thereof on the 100-ton basis.

SIZES.		Run No. 12.	Run No. 13.	Run No. 14.	Run No. 15.	Run No. 16.	Run No. 17.
Through.	On.						
mm.	mm.						
2.49	2.49	0.005					
2.06	2.06	0.061	0.001				
1.63	1.63	0.788	0.015	0.002			
1.44	1.44	0.602	0.026	0.001			
1.27	1.27	0.951	0.037	0.002			
1.10	1.10	0.676	0.014	0.002			
0.96	0.96	0.605	0.018	0.002	0.0003		
0.84	0.84	0.758	0.078	0.005	0.0003	0.001	
0.68	0.68	0.473	0.120	0.011	0.002	0.001	0.001
0.57	0.57	0.263	0.194	0.033	0.003	0.003	0.001
0.45	0.45	0.234	0.494	0.092	0.020	0.011	0.003
0.36	0.36	0.042	0.188	0.133	0.031	0.025	0.004
0.28	0.28	0.030	0.089	0.236	0.139	0.064	0.075
0.24	0.24	0.015	0.014	0.048	0.093	0.070	0.080
0.20	0.20	0.011	0.011	0.068	0.250	0.213	0.281
0.15	0.15	0.004	0.003	0.020	0.146	0.299	0.809
0.12	0.12	0.004	0.002	0.005	0.076	0.188	1.013
0.10	0.10	0.001	0.001	0.001	0.015	0.051	0.531
0.08	0.08	0.004	0.001	0.001	0.028	0.060	0.909
0.00	0.00	0.007	0.001	0.001	0.025	0.057	0.555
Total tons.....		5.534	1.307	0.663	0.828	1.043	4.262

Analyses of the above products giving percentages of galena (PbS) and quartz (SiO<sub>2</sub>).

Size.	Run No. 12.		Run No. 13.		Run No. 14.		Run No. 15.		Run No. 16.		Run No. 17.	
On.	Galena.	Quartz.	Galena.	Quartz.	Galena.	Quartz.	Galena.	Quartz.	Galena.	Quartz.	Galena.	Quartz.
mm.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.
2.49	0.00	100.00	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2.06	22.34	77.66	0.00	100.00	.....	.....	.....	.....	.....	.....	.....	.....
1.63	31.80	68.20	8.84	91.16	68.18	31.82	.....	.....	.....	.....	.....	.....
1.44	25.40	74.60	10.87	89.13	55.55	44.45	.....	.....	.....	.....	.....	.....
1.27	17.70	82.30	21.33	78.67	31.82	68.18	.....	.....	.....	.....	.....	.....
1.10	7.93	92.07	28.29	71.71	41.40	58.60	.....	.....	.....	.....	.....	.....
0.96	6.73	93.27	39.39	60.61	33.33	66.67	16.67	83.33	.....	.....	.....	.....
0.84	4.04	95.96	38.92	61.08	44.45	55.55	16.67	83.33	66.67	33.33	.....	.....
0.68	3.10	96.90	29.42	70.58	42.44	57.56	59.45	40.55	23.08	76.92	64.29	35.71
0.57	2.43	97.57	25.14	74.86	37.50	62.50	61.54	38.46	66.67	33.33	52.39	47.61
0.45	3.56	96.44	31.00	69.00	38.80	61.20	62.27	37.73	79.58	20.42	75.52	24.48
0.36	5.58	94.42	47.93	52.07	38.58	61.42	59.76	40.24	47.72	52.28	83.34	16.66
0.28	9.57	90.43	49.53	50.47	32.44	67.56	33.33	66.67	28.51	71.49	28.17	71.83
0.24	16.15	83.85	46.20	53.80	28.12	71.88	18.51	81.49	11.15	88.85	10.67	89.33
0.20	22.80	77.20	52.99	47.01	26.72	73.28	18.45	81.55	5.86	94.14	4.60	95.40
0.15	27.33	72.67	71.90	28.10	32.77	67.23	16.93	83.07	4.91	95.09	2.25	97.75
0.12	95.98	4.02	88.22	11.78	42.00	58.00	23.79	76.21	6.27	93.73	3.54	96.46
0.10	96.91	3.09	92.04	7.96	60.78	39.22	41.44	58.56	11.32	88.68	5.10	94.90
0.08	97.92	2.08	91.95	8.05	74.16	25.84	79.81	20.19	40.12	59.88	11.12	88.88
0.00	98.06	1.94	96.40	3.60	6.32	93.68	98.07	1.93	90.42	9.58	82.98	17.02
Total midd's	13.85	86.15	33.95	66.05	34.43	65.57	28.90	71.10	16.25	83.75	16.28	83.72

of concentrates is so good that it would be accepted by any mill, even the Missouri mills, where such clean concentration is required.

Looking at the middlings, Table XIV., we see that the quantity is extremely small, and can be made to disappear in a continuous run by feeding them back on to the table without harming either the concentrates or the tailings. They have, however, some very interesting features that are worthy of note. The galena in the 12th run runs high in the coarse and in the fine, and very low in the middle sizes, there being a great heaping-up of quartz in this part. This same point is true in the 16th and 17th runs to a very marked degree. It is again true to a less marked degree in the 14th and 15th runs, and it appears not to be true at all in the 13th run.

Looking at the tailings, Table XV., we see that run No. 12 stands out pre-eminent, having only 0.29 per cent. of galena in the whole tailings, and the tailings of runs Nos. 13 to 17 are very low in galena, and would probably pass in any concentrating establishment.

We have one feature here which does not and cannot happen in sized runs, Nos. 6 to 11—viz., the tailings get richer in galena down to the finer sizes; but when we look at the tonnage we find that there is scarcely any weight of material down in those sizes, and therefore this loss is not serious and does not bring up the percentage of galena in the final tailings to a serious extent.

Fig. 4 is an ideal sketch of what happens at the discharging-corner of a Wilfley table. Running from coarse on the lower edge to fine on the upper, *A, B, C, D, E, F, G*, and *H* represent the different sizes of galena. It appears that they arrange themselves approximately according to this order on the Wilfley table. In like manner, the quartz-grains arrange themselves approximately in order of size, beginning at the lower edge with the largest grade and running smaller and smaller upwards, as indicated by the letters *I, J, K, L, M, N, O*, and *P*. The slimes at once take off the galena (*H*), and the quartz (*P*). These finest of all grains have not sufficient weight to hold them up to the upper edge, where mathematical logic would place them. They therefore go into the slimes. The next grade, *G* (galena), and *O* (quartz), are not fine enough to

TABLE XV.—*Results of Runs Nos. 12 to 17 Computed to Full Size.*

NOTE.—The tailings have been sized and weighed and the weights computed in tons and fractions thereof on the 100-ton basis.

Size. On.	Run No. 12.	Run No. 13.	Run No. 14.	Run No. 15.	Run No. 16.	Run No. 17.
mm.						
2.49	0.042	0.043	.....	.....	.....	.....
2.06	1.762	1.336	0.056	0.027	.....	.....
1.63	18.040	18.429	2.083	0.023	.....	0.016
1.44	10.232	21.674	4.484	0.017	0.016	0.011
1.27	8.176	20.207	11.129	0.030	0.016	0.011
1.10	2.828	11.066	9.834	0.071	0.016	0.011
0.96	1.590	7.877	8.167	0.185	0.021	0.022
0.84	1.457	7.835	13.670	0.780	0.026	0.016
0.68	0.281	2.676	13.131	1.843	0.047	0.033
0.57	0.178	2.098	11.080	7.316	0.163	0.044
0.45	0.103	1.122	14.410	21.851	2.381	1.945
0.36	0.021	0.121	4.532	20.371	5.709	5.423
0.28	0.019	0.097	2.604	30.530	34.072	31.480
0.24	0.015	0.038	0.437	5.486	17.393	17.182
0.20	0.017	0.024	0.220	4.473	18.103	19.917
0.15	0.012	0.019	0.087	0.790	10.150	10.175
0.12	0.015	0.014	0.033	0.240	3.129	2.845
0.10	0.002	0.009	0.010	0.084	1.249	0.911
0.08	0.010	0.029	0.010	0.071	0.580	0.544
0.00	0.017	0.029	0.012	0.044	0.169	0.172
Total tons.....	44.817	94.743	95.939	94.232	93.240	90.758

Analyses of the above products giving percentages of galena (PbS) and quartz (SiO<sub>2</sub>).

Size.	Run No. 12.		Run No. 13.		Run No. 14.		Run No. 15.		Run No. 16.		Run No. 17.	
On.	Galena.	Quartz.	Galena.	Quartz.	Galena.	Quartz.	Galena.	Quartz.	Galena.	Quartz.	Galena.	Quartz.
mm.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.
2.49	0.00	100.00	0.00	100.00	.....	.....	0.00	100.00	.....	.....	.....	.....
2.06	0.00	100.00	0.00	100.00	0.00	100.00	0.00	100.00	.....	.....	.....	.....
1.63	0.00	100.00	0.08	99.92	0.00	100.00	0.00	100.00	.....	.....	.....	.....
1.44	0.52	99.45	0.07	99.93	0.09	99.91	0.00	100.00	0.00	100.00	0.00	100.00
1.27	0.20	99.80	0.48	99.52	0.06	99.94	0.00	100.00	0.00	100.00	.....	.....
1.10	0.38	99.62	0.09	99.91	0.06	99.94	0.00	100.00	0.00	100.00	.....	.....
0.96	0.67	99.33	0.18	99.82	0.03	99.97	0.00	100.00	0.00	100.00	.....	.....
0.84	0.74	99.26	0.18	99.82	0.03	99.97	0.00	100.00	0.00	100.00	.....	.....
0.68	0.76	99.24	0.54	99.46	0.02	99.98	0.00	100.00	1.10	98.90	.....	.....
0.57	1.20	98.80	1.16	98.84	0.02	99.98	0.00	100.00	0.32	99.68	0.00	100.00
0.45	1.03	98.97	6.04	93.96	0.10	99.90	0.17	99.83	0.86	99.14	1.36	98.64
0.36	1.28	98.72	16.00	84.00	0.84	99.16	0.23	99.77	0.45	99.55	0.69	99.31
0.28	7.08	92.92	33.05	66.95	2.08	97.92	0.98	99.02	0.17	99.83	0.34	99.66
0.24	9.22	90.78	27.60	72.40	3.88	96.12	0.27	99.73	0.30	99.70	0.58	99.42
0.20	5.64	94.36	19.00	81.00	5.21	94.79	0.43	99.57	0.35	99.65	0.55	99.45
0.15	5.90	94.10	13.32	86.68	7.73	92.27	3.30	96.70	0.44	99.56	0.54	99.46
0.12	7.50	92.50	15.30	84.70	9.59	90.41	8.97	91.03	0.87	99.13	1.01	98.99
0.10	5.40	94.60	40.40	59.60	72.79	27.21	17.32	92.68	1.83	98.17	2.07	97.93
0.08	28.38	71.62	55.55	44.45	21.43	78.57	26.55	73.45	7.04	92.96	7.38	92.62
0.00	85.93	14.07	87.00	13.00	68.68	31.32	68.32	31.68	42.36	57.64	44.28	55.72
Total tail'gs.	0.29	99.71	0.36	99.64	0.20	99.80	0.55	99.45	0.46	99.54	0.66	99.34



go into the slimes nor coarse enough to stand up against the water-current in the position shown in the sketch. These grains are found, therefore, sprinkled through the concentrates, middlings and tailings. See the heaping-up of galena in the small sizes in Tables VIII., IX. and X.

Having laid out our argument in this way, it now remains for us to compare by means of this diagram runs Nos. 1 to 5,

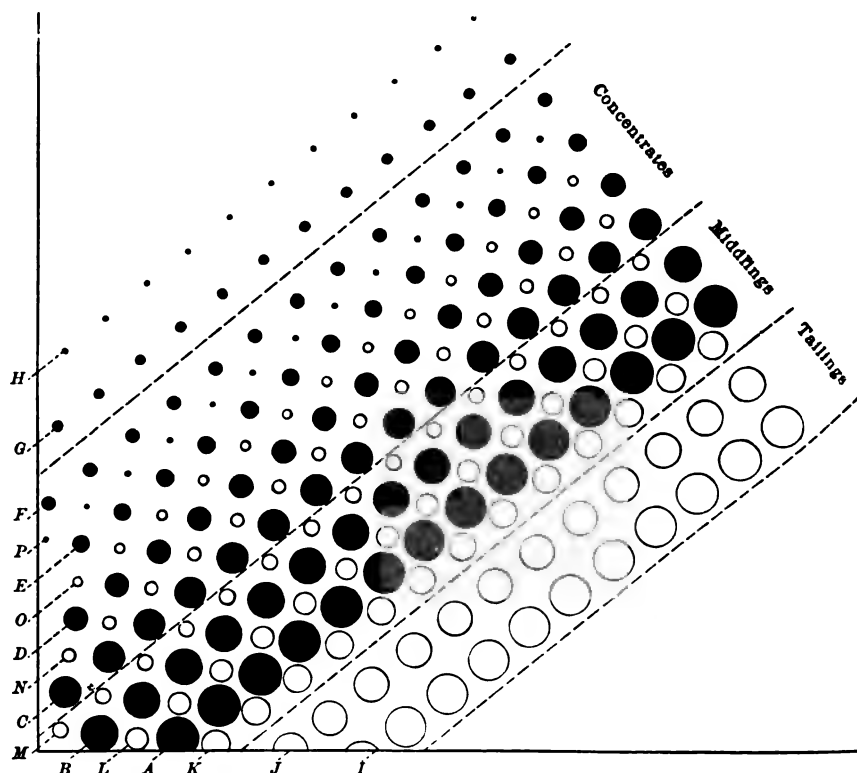


FIG. 4.—IDEAL SKETCH OF THE ARRANGEMENT OF GRAINS BY A WILFLEY TABLE.

6 to 11, and 12 to 17, and to see why it is that runs Nos. 6 to 11 and Nos. 12 to 17 are so much better than runs Nos. 1 to 5. Runs Nos. 1 to 5 take the products just as they are shown in Fig. 4 and give galena, *C, D, E, F*, in the concentrates contaminated by quartz, (*N*). See the heaping-up of the quartz a little below the middle size in Table VIII., and the middlings that give quartz, *K, L*, and *M*, contaminated by galena, *A, B*,

*C*, and *G*. See the heaping-up of galena among the large grains and among the small grains in Table IX., and the tailings have in them the quartz, *I*, *J*, and *O*, contaminated by galena, *G*. See the heaping-up of galena in the fine sizes in Table X. Runs Nos. 6 to 11, on the other hand, have put together on the coarse table, quartz, *I*, and galena, *A*, which have nothing whatever to do with one another (see Table XII.), and therefore make almost 100 per cent. of galena in the concentrates, and almost 100 per cent. of quartz in the tailings. The little accidental middling-product, simply being the dividing-line between the two products, goes back on the table and disappears. On the second table we treat quartz, *J*, and galena, *B*, with the same result. On the third table we treat quartz, *K*, and galena, *C*, with the same result. On the fourth table quartz, *L*, and galena, *D*; on the fifth table quartz, *M*, and galena, *E*; on the sixth table quartz, *N*, and galena, *F*. There seems no reason logically why these should not turn out 100 per cent. of galena in the concentrates and 100 per cent. of quartz in the tailings. The probable reason why we did not obtain those figures was that the accidental flat scales and the fine abrasions of galena went where they should not.

Going to the third set of runs, Nos. 12 to 17, we need to bring in an ideal picture of the products of a classifier by means of Fig. 5. Suppose, for example, that we drop into a tall tube of water grains of quartz ranging from our maximum size down to zero, and grains of galena in the same way, and that these grains are of approximately the same shape, then the rate of settling of these grains may be stated in the following terms: the larger grains of a single mineral will settle faster than the smaller grains; and when we compare the two gravities of quartz and galena, the higher gravity will settle faster than the lower gravity for the same size. So definite is this law that if we look for equal-settling particles, we shall find that the grain of quartz which is equal-settling with the grain of galena is about 3 or 4 times the diameter of the grain of galena. See settling-ratios in Table III. We may, therefore, construct the ideal diagram, Fig. 5, and we can draw a set of horizontal lines across it, putting the equal-settling grains together, ranging from the heavier grains of the first spigot in the lower part of the diagram up to the lighter grains of the

finer spigot at the upper part of the diagram. We see then that spigot 1 contains an immense amount of galena ranging from the coarsest size down to one-quarter the diameter of the coarsest quartz, and that the quartz is almost all in the coarse sizes. See spigot 1, Table III. This is exactly what we found in our run No. 12. See the heaping-up of galena in the large sizes in Table XIII.

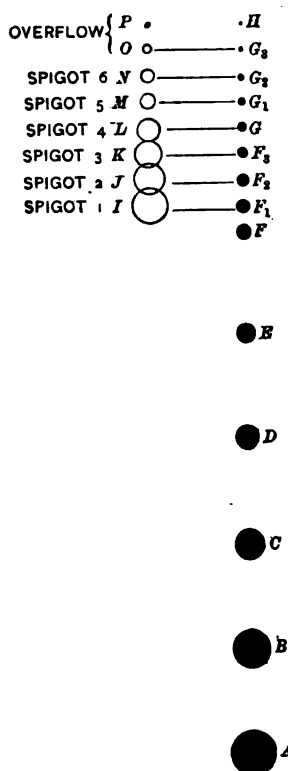


FIG. 5.—IDEAL SKETCH OF CLASSIFIER-PRODUCT.

Spigot 2 has small galena and large quartz, but the two are a little smaller than those in spigot 1. Spigot 3, again, has small galena and larger quartz, but a little smaller than spigot 2, and so on up the scale with spigot 4, spigot 5 and spigot 6. See the heaping-up of galena in smaller sizes, Table XIII., and of quartz in larger sizes in Table XV.

Looking at our diagram, Fig. 4, to see what will happen when these several spigots are put upon the table, we shall

find that run No. 12 receives galena, *A, B, C, D, E, F,* and *G*, and quartz, *I*. Logically these have nothing to do with one another, and therefore should make for perfect separation. Spigot 2 fed in run No. 13 would have quartz, *J*, and galena, *F*<sub>2</sub>. Spigot 3 would have quartz, *K*, and galena, *F*<sub>3</sub>, and so on. Spigots 4, 5, and 6 could work their way up, having quartz always larger, and therefore belonging at a lower place on the table, and galena of smaller diameter belonging at a higher place on the table, making for clean separation of concentrates and tailings, with a middling product that can go directly back on the table and disappear. In proof of this, see points of heaping-up of galena and quartz in Tables XIII. and XV.

In the light of Fig. 4, comparing runs 12 to 17 with runs 6 to 11 we see that the natural lines for quartz and galena are farther apart for the classified products than for the sized products. For example, in run 12 the galena lines *A* to *F* average farther from the quartz *I* than does the galena *A* of run 6. Again, in run 13 the galena *F* is farther from quartz *J* than is the galena *B* from quartz *J* in run 7. In like manner we may compare classified runs 14, 15, 16, and 17 with sized runs 8, 9, 10, and 11.

This demonstrates that with perfect classification the work will be better done on the Wilfley table than with sizing, and it also shows that with much middle weight mineral or included grains a good classifier will probably be more efficient than screens.

#### CONCLUSIONS.

1. The natural product as feed for a Wilfley table is completely outclassed and surpassed by sized-product feed and by classifier-product feed.

2. While the sized-product feed, as shown in Table VII., appears to have done better work than the classifier-product feed, if we give full weight to the great performance of run No. 12, we can agree that this has fully offset the slight falling-off of runs Nos. 13 to 17, and that the classifier-feed work is fully up to the sized-feed work on the Wilfley table, and with a perfect classifier the work will be better done than with screens.







**WILLIAM GEORGE NEILSON.**

## **Biographical Notice of William George Neilson.**

**BY JOHN BIRKINBINE, PHILADELPHIA, PA.**

**(New York Meeting, April, 1907.)**

MR. NEILSON was born Aug. 12, 1842, at Philadelphia, Pa., where he died Dec. 30, 1906. His business career began with his graduation, in the class of 1862, from the Polytechnic College of the State of Pennsylvania.

For a short time after graduation he was instructor in mathematics at the college, and then became associated with Messrs. Booth & Garrett, chemists, of his native city. In 1867 he was sent to the Adirondack mountains to care for mining interests of the late Jay Cooke, and spent about three years there, operating the forges at Elizabethtown, Essex county, N. Y. He also prepared an interesting monograph on Catalan forges and their operations.

In 1868 he published a chart showing the material progress of the United States, and the cost of certain staple products during a series of years, which is believed to be the first of its kind issued in this country. In 1870 he made a trip to the Pacific Coast, prior to entering the service of the Pennsylvania Steel Company.

In 1871, when the Logan Iron & Steel Co., of Burnham, Pa., failed, Mr. Neilson was appointed receiver, re-organized the company, became its General Manager, and spent more than four years in this work. In the meantime, he became interested in the Freedom forge of the same place, and, with Mr. Wm. Burnham and Mr. Milton Brosius, laid the foundations for what is now the Standard Steel Works. From Jan. 1, 1877, to April 1, 1890, he was General Manager of these works, and closely associated with the Baldwin Locomotive Works. In 1878 he was in charge of the first consignment of Baldwin locomotives to Europe, which, with a picked crew of men from Baldwin's, he took to Eydtkennen, Russia, and placed in service.

In 1890 he resigned from the Standard Steel Works and ac-



cepted a position in connection with the Chester Rolling Mills; later, he became and remained until 1893 Vice-President of the Wellman Iron & Steel Co. From 1893 to the end of 1895 he was General Manager of the Taylor Iron & Steel Co., of High Bridge, N. J.

For the past eight years Mr. Neilson had been the Treasurer of the Keystone Drop Forge Works, of Chester, Pa.

While Mr. Neilson was with the Standard Steel Works he became interested in a large tract, at the head of Keene valley in the Adirondacks, which was about to be sold for its timber. Forming a company, chiefly of Philadelphia and New York men, he purchased this property and established the Adirondack Mountain Reserve, of which he served as President for 17 years, and which tract remains to-day one of the most attractive forest-preserves in the Adirondack region. He was always interested in forestry, and for many years was a member of the Pennsylvania Forestry Association.

He was a member of the Protestant Episcopal Church and active in its work. He was also for many years a Director of the Union Insurance Co. of Philadelphia, and was actively interested in the Young Men's Christian Association of Philadelphia, serving as President during the years 1899, 1900, and 1901, and as Director continuously, after Jan. 1, 1888, until the time of his death.

Mr. Neilson's connection with the Institute began in 1872, the year after its organization, and continued until his death. From the beginning, he was loyal and enthusiastic in his support of the Institute. In 1876 he was selected as Secretary of the "Centennial Committee," which collected and administered, in the name of the Institute, a special fund of a little more than \$4,000, in the maintenance of headquarters, for the entertainment and information of visiting engineers, at the Centennial Exposition in Philadelphia. At these headquarters a professional *conversazione* was held weekly, and an address was made by some distinguished expert. Moreover, the rooms were kept continuously open, and provided with guide-books and much other appropriate literature and maps, while the Secretary and his assistants were always prepared to assist with advice, introductions, etc., visiting colleagues engaged in professional inspections, inside or outside of the Exposition. Thus, there were

furnished to foreign guests 493 written letters (besides innumerable cards) of introduction, and 43 detailed schedules of journeys, accompanied with maps of the United States, upon which the routes of these journeys were laid down.

The management of this difficult undertaking was intrusted to Mr. Neilson; and the results he accomplished with the relatively small sum at his disposal surprised even those of his friends who had had reason already to rely upon his executive ability. The headquarters under his charge were gratefully used by hundreds of visiting engineers, and the weekly reunions were numerous attended and greatly enjoyed. Foreign guests were greatly impressed with the novelty and usefulness, as well as the cordiality of this form of professional courtesy, and foreign technical literature was loaded with their acknowledgment of it. Among the results of this general recognition was the donation to the American Institute of Mining Engineers of mineral and metallurgical exhibits from Germany, Sweden, Russia, Spain, Portugal, Austria, Italy, Belgium, England, the Australian colonies, Canada, Brazil, Mexico, and the United States, amounting in estimated value to about \$250,000.<sup>1</sup> The Emperor of Germany, in recognition of the services rendered by Mr. Neilson to visiting German engineers, decorated him with the Order of the Red Eagle, fourth class.

The report of the Centennial Committee, cited above, reads as follows:

"The Committee cannot close its report without thanking its Secretary, Mr. William G. Neilson, for the energy, ability and fidelity with which he discharged his onerous duties; and also Mr. Edward Nichols, who, from April 1 to Dec. 1, 1876, was the Assistant Secretary, and ably assisted Mr. Neilson in all his duties."

In this connection it is interesting to observe that the only contribution made by Mr. Neilson to the *Transactions* was an appreciative Biographical Notice of Mr. Nichols,<sup>2</sup> who died in 1892.

It is not too much to say that this intelligent and well-organ-

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<sup>1</sup> See report of the Centennial Committee, *Trans.*, v., 31 (1876-7). These collections were first left with the Pennsylvania Museum and School of Industrial Art, and subsequently (1882) transferred to the National Museum at Washington, D. C. See *Trans.*, x., 243 (1881-2).

<sup>2</sup> *Trans.*, xxi., 76 (1892-3).

ized enterprise of professional and international courtesy did more to win recognition for the Institute, throughout the world, than any other single event in its history, and that the credit for this happy result was chiefly due, not to the Committee which suggested the plan, but to Mr. Neilson, who successfully executed it.

On Jan. 2, 1907, numerous friends gathered at the funeral service and bade a sorrowful farewell to one who had been loved and esteemed by all present, and whose memory will be cherished by many friends in and beyond the American Institute of Mining Engineers. We saw in the casket the peaceful expression which had been familiar to us for many years; except for the gray hair, it seemed to me to be the same expression of friendly recognition which characterized him when, as college students, we first met. It bore no sign of suffering. Death called him at his office desk on the last Saturday of the year 1906, and as he closed his accounts with his business he passed from earth.

As a collegian and alumnus, highly esteemed; as a friend, beloved; as a business man, respected and trusted; as a Christian, earnest; as the head of a family, affectionate and wise; in all things faithful, Mr. Neilson had a host of friends which his home could not accommodate as mourners. Nor are the mourners confined to our own country; for in his European journeys, and in the service which he rendered to the Institute, as above described, he made many friends abroad whose sorrow at his death echoes that of his own countrymen.

## Biographical Notices of 1906.

(Toronto Meeting, July, 1907.)

THE list of deaths during the year 1906 comprises the following names, the figures in parentheses indicating the year in which the persons named were elected to membership:

*Members and Associates.*—Arthur Vaughan Abbott (1882), William Anderson Akers (1889), R. Scott Allen (1905), George H. Arlett (1900), Thomas Septimus Austin (1883), Thomas T. Baker (1887), William Tittley Batchelor (1902), Charles Lowthian Bell (1897), Edgar Vallentine Bensusan (1892), George Lothrop Bradley (1874), Ernst Elmer Breisch (1896), Horace F. Brown (1895), James A. Burden (1876), Alexander B. Coxe (1880), George A. Crocker (1879), Albert W. Fiero (1886), John Herbert Fraser (1904), Robert Gibson (1892), R. G. Hart (1900), Christopher Henne (1900), Alexander W. Jolly (1899), George L. Keener (1900), Winfield Scott Keyes (1872), John G. Lanning (1893), Gustavus W. Lehmann (1891), Nicholas Lennig (1882), William H. Long (1882), Frank C. Mandell (1905), Edmund H. Miller (1895), John Fossbrook Morris (1903), F. J. Odling (1893), William Painter (1893), Stanley H. Pearce (1896), Herman Poole (1900), Ricardo G. Ramos (1898), Arthur F. Rising (1904), George H. Robinson (1886), Albert W. Sayles (1905), Richard J. Seddon (1888), James C. Simpson (1887), Francis Lewis Sperry (1889), John Stanton (1877), Edward G. Stoiber (1877), Samuel Thomas (1871), Abel Hyde Toll (1900), John Price Wetherill (1896).

Of these, Alexander B. Coxe, Thomas S. Austin and Samuel Thomas have been made the subjects of special Biographical Notices. That of Alexander B. Coxe was printed in *Bi-Monthly Bulletin*, No. 11, September, 1906, pp. 701 to 705, and those of Messrs. Austin and Thomas will be presented in later issues of this publication. Concerning the remainder of the list, the following paragraphs comprise such information as could be obtained by the Secretary:

*Arthur Vaughan Abbott*, civil, mechanical and electrical engineer and author, was born in 1854 at Brooklyn, N. Y., and graduated, 1875, from the Brooklyn Polytechnic Institute. After 1 year in the Department of Parks, he served for 7 years as an assistant engineer in the construction of the Brooklyn (suspension) bridge over the East river, in which capacity he designed and perfected many important details, including a splice for cable-wire, and machinery for wire-cutting and for testing the crucible-steel wire used in the bridge. He superintended the cable-construction, and the inspection of all materials. After the completion of the bridge, he was connected for 4 years with the E. T. Fairbanks Co., manufacturing scales and testing-machines. About 1887, he became chief engineer of the Boston Heating Co., for which he built a central station, to supply heat through pipes conveying superheated water over an area of 2 sq. miles. In later years, he turned his attention specially to electric engineering, a field in which he achieved a large practice and a high reputation. As mechanical engineer of the Daft Electric Light Co., he reorganized the business of manufacturing dynamos and motors. At various times he built and put in operation electric railways at Meriden, Conn., Bloomfield and Atlantic City, N. J., Bloomington, Ill., Ogden, Utah, and Augusta, Ga. He also operated storage-battery cars on 4th Ave., N. Y. City, and directed the electric equipment of the Lake Roland line, Baltimore, Md., and the Interstate railroad, Kansas City, Mo. He was consulting engineer for the Ogden City water-works, the Bear river irrigating canal, Utah, and the Waukesha pipe line, Wis. For a long time, beginning in 1892, he was chief engineer of the Chicago Telephone Co., designing, installing and operating its central station and branches, and directing its underground work and its lighting-system. He was consulting engineer and chief of the statistical department of Westinghouse, Church, Kerr & Co.

Mr. Abbott's published works comprise books on the Electrical Transmission of Energy; the Evolution of a Switchboard; the History and Use of Testing-Machines; Fuel, and Telephony.

He was a member of the American Society of Civil Engineers; the American Society of Mechanical Engineers; the American Institute of Electrical Engineers, of which he be-

came Vice-President in 1902; and this Institute, which he joined in 1882, before the two last-named societies, representing more closely his special lines of practice, came into existence. Yet he retained to the last his membership and loyal interest in our society, participating in its meetings, and contributing to its *Transactions* several important professional papers, on Improvements in Methods for Physical Tests (*Trans.*, xii., 607); The Present Value of Steel Castings (xiv., 351); and A Description of the Plant of the Boston Heating Company (xvi., 870).

Mr. Abbott died December 1, 1906, of pneumonia, after a brief illness, in New York City, where he had finally established his residence and his office as a consulting engineer. His death brought a shock of surprise, as well as sorrow, to a large circle—or more accurately, in view of the variety of his activities and achievements, to several interlocking and overlapping circles—of his friends and colleagues. Since he had attained the age of 52, and had been in continuous professional practice for 31 years, it cannot be fairly said that he was cut off after an exceptionally short career; and this declaration would be still further discredited by a survey of the remarkable record of good work in many departments with which he crowded those 31 years. Yet, on the other hand, the loss of such a man in the prime of his strength and in the midst of his work, depriving the world of the benefit of his ripe judgment and wide experience, profoundly disappointed a well-founded hope of further and even more valuable service. In short, Arthur V. Abbott lived long enough to establish his own reputation, but died too early to satisfy the needs and the expectations of his fellows. Moreover, his cheerful vivacity, eager activity and gentle courtesy gave us all the impression of a youthfulness which makes us now involuntarily think of him as one whom both gods and men loved, and who died young.

*William Anderson Akers* was born February 5, 1860, at Lexington, Mo. His childhood and youth were passed in Missouri and Kentucky. In the early 80's he went to Montana and engaged in practical mining at Butte, subsequently taking a course of study at Columbia University, N. Y. Thus equipped, he became Manager for the Combination Mining Co., at Black

Pine, Mont., afterwards managing the Sheridan-Mendota mine, Telluride, Colo., and the Golden Fleece mine, Lake City, Colo. Later, he engaged in professional work, with headquarters successively in Denver, Colo.; Salt Lake City, Utah; Butte, Mont.; and El Paso, Texas, finally settling in Los Angeles, Cal., where he died June 17, 1906, of injuries received in an automobile accident on the preceding day.

Mr. Akers joined the Institute in 1889, and, in collaboration with C. W. Goodale, contributed to the *Transactions* (xvii., 242-252) a paper on Concentration before Amalgamation for Low-Grade Partially Decomposed Silver Ores, with Notes on the Geology of the Flint Creek Mining District.

*George H. Arlett* was born at Wellend, Little Marlow, England, November 21, 1853, and died March 19, 1906, at Chihuahua, Mexico. He came to America in 1861 with his parents, who settled at North Adams, Mass., where he received his schooling at the Drury Academy. From the age of 18 to 24, he was employed in the cotton-mills and in railroad work. About 1877, the family removed to Denver, and in 1885 to Cañon City, Colo. As a youth, in North Adams, he had studied chemistry with much interest, and in Colorado he took up assaying and other metallurgical work. In Cañon City he held the position of chemist for the Royal George Smelter (Messrs. Harp, Taylor & Co.), and, later, for the American Mining & Smelting Co. Subsequently, he went to Mexico, where he served as metallurgist at the Hacienda Saldaña, San Juan de Guadalupe, Durango, and chemist and metallurgist for the St. Louis & Zacatecas Ore Co., City of Mexico. He was also chemist of the Santa Rita Mining Co., Santa Rita, New Mexico. In 1901 he formed a business connection with Mr. G. W. Boyce, Boston, Mass., in whose interest he went to Chihuahua, Mexico, for the development of mining-properties in that region; at Terrazas, Victorino, Casi, etc., and continued in this work as mining engineer and metallurgist until his death. Mr. Arlett became a member of the Institute in 1900.

*Thomas T. Baker*, one of the best known mining engineers of Montana, died at his home in Butte on April 30, 1906, aged 66 years. Mr. Baker was born and brought up on a farm in

what is now West Virginia. At the outbreak of the Civil War he enlisted on the Union side with the Fifteenth West Virginia regiment, and served till the close of the war. He attained the grade of second lieutenant, and it was a source of gratification to him throughout his life that at Appomattox he was in charge of one of the companies detailed to receive the arms of the surrendering Confederate troops. He also served in the Shenandoah, and was at the battle of Winchester on the arrival of General Sheridan after his famous ride. Prior to his enlistment as a volunteer soldier, Mr. Baker had had no school advantages whatever, but after the war he attended Iowa College at Grinnell, first entering the academy and later the college department. He earned his own way and was graduated from the college in 1874. Mr. Baker was not a man who acquired knowledge easily or quickly, but he was very thorough; he had a wonderful memory, and he never ceased to grow mentally, so that what he learned he retained, and during his later years his fund of accurate information became really impressive. After graduation Mr. Baker took up the profession of engineering. He located in Butte in 1878, when the now famous copper city was a young and struggling mining camp. Securing an appointment as a Deputy United States Mineral Surveyor, he began the work of surveying mining-claims for patent. At the time of his death he no doubt had surveyed for patent more mining-claims than any other surveyor in the State and, perhaps, in the United States.

Mr. Baker was a giant in stature, being over six feet tall and built like an athlete. He was impatient of shams of all kinds, and to strangers appeared brusque, but his intimate acquaintances knew him to be at heart very kind and considerate of the rights of others. In his impregnable honesty everybody had confidence, and his death was widely mourned in Montana. He joined the Institute in 1887.

*William Tittley Batchelor* was born at Launceston, Tasmania, in 1872. He received his technical education in the office of Charles K. Sheard, under whose direction he was employed on railroad-surveying and construction and harbor-works from 1887 to 1893. In the latter year, he was appointed assistant engineer in surveying and construction work of the Mt. Lyell



Mining & Railway Co., Ltd. He was subsequently advanced to the position of engineer in charge of the mines of that company, with headquarters at Gormanston, West Coast, Tasmania, and held this position until his death, which occurred on September 27, 1906. He became a member of this Institute in 1902.

*Charles Lowthian Bell*, the second son of the late Sir Lowthian Bell, who not only inherited but worthily earned our esteem and affection like that which was universally bestowed upon his distinguished father, was born March 24, 1855, at Washington Hall, near Durham, England, and died February 8, 1906, after a brief illness, at his residence near Middlesbrough. The following account is adopted from the memoir published in the *Proceedings of the Institution of Mechanical Engineers* for 1906:

“Charles Lowthian Bell was the second son of the late Sir Lowthian Bell, and was born at Washington Hall, the seat of his father near Durham, on 24th March, 1855. He was educated first at a preparatory school at The Mount, Northallerton, and subsequently at Wellington College. After leaving Wellington he proceeded to Paris and continued his studies at the *École des Mines*, whence he went to the well-known works of Schneider & Co., at Le Creusot, where he remained about a couple of years. He then returned to England, and, after occupying various subordinate positions in the firm of Messrs. Bell Brothers, he undertook the management of the furnaces at Walker-on-Tyne in the year 1881. Three years later he removed to Clarence as Assistant Manager under Mr. John Thompson. On the death of this gentleman in 1887 he became manager of the Clarence Works, and under his superintendence the whole arrangements were re-modeled, Cowper firebrick stoves being substituted for pipe stoves, and the blowing machinery and boiler plant entirely reconstructed to permit the utilization of the waste heat for the manufacture of salt. In addition to these important changes, a by-product coke-oven plant was erected by Messrs. Bell Brothers in conjunction with the German Actien-Gesellschaft für Kohlendes-tillation, the elaborate arrangements for sorting and washing the coal required for this plant being planned by him. He re-

mained in charge of the Clarence Works until 1904. Shortly before his father's death in December of that year he decided to resign his position and to take a less active part in the management, though he remained a director of the Company.

"Following in the footsteps of his father, he paid numerous visits to ironworks abroad, both in Europe and America, accompanying his father on one of his visits to the latter country. On the flotation of Messrs. Bell Brothers, Limited, in 1899, as a public company he and Mr. W. H. Panton paid another visit to America to study the processes of steel manufacture in that country, and they also visited various works in Europe for the same purpose. The information then acquired was utilized in designing the steel plant at Clarence. Already in 1886 the attention of Sir Lowthian Bell and his partners had been turned in the direction of the manufacture of steel from Cleveland iron, and a small plant had been erected under designs, in the preparation of which Mr. C. L. Bell took a large part. A considerable quantity of steel was produced at this establishment, but circumstances prevented the project being carried forward, and for some years the works lay idle. In 1898, by arrangement with Messrs. Dorman, Long & Co., experiments which the latter firm had begun at Rosebery Steel Works, near Middlesbrough, were continued at the works at Clarence, put at the disposal of the firm by Sir Lowthian Bell and his sons. Under the direct supervision of Mr. W. H. Panton, assisted by Mr. C. L. Bell, a series of experiments resulted in a satisfactory solution of the problem, the flotation of the firm as a public company and the erection of the present important plant at Clarence being the direct results of these operations.

"Over and above the many activities he displayed in connection with the Works at Clarence (where not only the Iron Works, but also the Salt Works and Soda Works, until they were sold to the Salt Union, and Messrs. Brunner, Mond and Co., respectively, were under his control), he took an active part in the volunteer movement. He joined the North Riding Volunteer Artillery in 1874 and took command of the Corps in 1895 as Lieutenant-Colonel, becoming a year later the Honorary Colonel, resigning his command in 1902 on reaching the age limit. During the South African War he was the means

of raising and equipping two Colt-gun detachments and of sending out 400 men for the Imperial Yeomanry. He was for some time a member of the Middlesbrough Town Council, serving the office of Mayor in the year 1898, when he welcomed the Members of this Institution on the occasion of their Summer Meeting; and he was for many years an active member of the Stockton Board of Guardians. He was on the Commission of the Peace for the North Riding and for the County of Durham, and also for the Borough of Middlesbrough. His death took place at his residence near Middlesbrough, after a very short illness, on 8th February, 1906, in his fifty-first year."

The Secretary of the Institute desires to add to the foregoing statement, for himself and for many other American members who had learned to love Charles Lowthian Bell as they had loved his father, an expression of their personal loss and sorrow in his too early death.

*Edgar Vallentine Bensusan* was of Australian birth, and gained his education at the leading colleges of Sydney, N. S. W., and at the Royal School of Mines, London. After graduation, he was metallurgist and manager of the refinery of the Sunny Corner silver-mines, N. S. W., for a number of years, next becoming general manager of the Cullen Bullen colliery, Butlers. Later, he managed the Dutchman's tin-mine, N. S. W., which he owned, and other properties in the same State. With his brother, A. J. Bensusan, A.R.S.M., F.C.S., M.S.M.M., now manager of the Ouro Preto Gold-Mines of Brazil, Ltd., he formed a partnership as consulting mining engineers, which continued for some years. In November, 1901, he went to England and was appointed manager of the Fanti Mines, Ltd., for which company he visited South Africa in 1903 to study methods of mining and metallurgy. Soon after his return to England he again went to Africa as general manager of a group of mines on the West Coast, comprising the Abbontiakoon Block I, Ltd.; the Abbontiakoon (Wassaw) Mines, Ltd.; the Effuenta (Wassaw) Mines, Ltd.; the Fanti Mines, Ltd.; and the Wassaw West Amalgamated Mines. He died at sea, May 8, 1906, at the age of 42 years, while returning to London from Cape Town. Mr. Bensusan had traveled much, and was

widely known as an engineer of sterling character and pronounced ability. He enjoyed the affection and esteem of his associates in an exceptional degree.' He was an Associate of the Royal School of Mines, London, and a member of this Institute since 1892.

*George Lothrop Bradley*, a son of Chief Justice Bradley, of the Rhode Island Supreme Court, was born at Providence, R. I., October 4, 1846. He was professionally educated at Freiberg, Germany, where he received special training in metallurgical engineering. On his return to the United States he went to Colorado to develop a mining-property in which his friends were interested. This venture proving less successful than had been anticipated, he returned to Providence, where he became acquainted with Prof. Alexander Graham Bell, then teaching a new system of "visible speech" for mutes, and, at the same time, perfecting his invention of the telephone. Mr. Bradley became interested in Prof. Bell's experiments, and, when the telephone had been brought to successful technical and commercial form, he organized in Boston the New England Telephone Co., and afterwards, in New York, the National Bell Telephone Co. Meanwhile, the Western Union Telegraph Co. had acquired the Edison telephone patents. The famous legal battle which followed ended in a compromise giving the Bell Company almost complete control of the field. At the close of this telephone litigation Mr. Bradley removed to Washington, D. C. At that time the Mergenthaler linotype had been on the market about six years, but had not achieved commercial success, and was making little progress. The insight that had guided Mr. Bradley in his connection with the Bell telephone in the least promising period of its development enabled him to discern the possibilities of the linotype. With the assistance of Wm. C. Whitney, he established the Mergenthaler Company on a secure foundation, and the machine speedily took the leading position which it has since held.

Mr. Bradley was an accomplished linguist, and had traveled extensively, visiting nearly all parts of the globe. His genial nature and lovable qualities brought him the affection and esteem of all his associates. The gift, in his will, of the Bradley homestead in Providence, to be used as a home for sufferers

from nervous and other chronic diseases, with generous provision for its maintenance, was a fitting climax to a lifetime of helpfulness. An attack of pneumonia, following a serious operation on his throat, caused his death, at Washington, D. C., March 26, 1906. Mr. Bradley joined the Institute in 1874, and although circumstances led him, not long after, to turn his attention and win a handsome fortune, in industrial applications of science not directly connected with mining or metallurgy, he never lost his loyal interest in the profession for which he had been primarily educated, or his desire to be considered still a member of its brotherhood. The earlier officers of the Institute had frequent reason to acknowledge his hearty co-operation and active assistance, and to recognize him as one of the company (now sadly depleted by death) of those enthusiastic and steadfast supporters upon whose faith and courage its foundations were laid.

*Ernst Elmer Breisch*, who died in Moundsville, Pa., February 14, 1906, was born near Bloomsburg, Pa., December 13, 1868; was graduated in 1888 from the State Normal School at that place; and in 1894 from the Pardee Scientific School of Lafayette College, Easton, Pa.; and in 1897 received from the same institution the degree of Mining Engineer. In 1895 he became engineer for the collieries of M. S. Kemmerer & Co., at Mauch Chunk, Pa., remaining there until 1902, when he went to the works of James W. Ellsworth & Co., at Ellsworth, Washington county, Pa. From June, 1903, to August, 1905, he was with the Glen Easton Coal & Coke Co., at Moundsville, as their chief mining engineer, retiring on account of ill-health, and dying about six months thereafter. Mr. Breisch was a quiet, unassuming, but loyal, industrious and efficient member of his profession. He joined the Institute in 1896.

*Horace F. Brown* was born in 1840 at Litchfield, Mich., and died at Chicago, April 15, 1906, of heart-failure. In 1862 he engaged in gold-mining and mine-surveying at Plumas, Cal. The year after he went to the Reese river district, Nevada, where he erected a mill for free silver amalgamation—a process which proved impracticable with the refractory ores of the district. In 1864 he removed to Virginia City, where he found

work in connection with the Comstock silver-mills, and in the early lead-smelting camps of the Sierra Nevada. Having invented a continuous coal-cutting machine, he visited the collieries of Pennsylvania, Indiana and Illinois, for the purpose of introducing it into practice. This endeavor was defeated at the time by the opposition of both miners and managers; but after the expiration of his patents machines of the type he had originated came into use. During his stay in the coal-regions, he installed in the Fall Brook colliery a system of underground wire-rope haulage, which is said to have been the first in the State of Pennsylvania.

For 3 years Mr. Brown was connected with the Hecla Cons. Mining Co., Beaverhead county, Mont., where he designed and built furnaces for the treatment of lead-copper matte, which had been, up to that time, sent to Germany. After this, as Superintendent for more than 2 years of the Alta Montana Co., near Helena, Mont., he designed and erected the whole of its plant except the free-gold stamp-mill, and directed both the mining and the metallurgical work. His health having suffered from lead- and arsenic-poisoning, he retired from this branch of practice, to establish and manage the Western Iron Works at Butte, Mont., for the manufacture and erection of mining and metallurgical plants; acting also as consulting engineer, especially in the remodeling of plants and their adaptation to local ores and conditions.

Mr. Brown's modification of the O'Hara mechanical roasting-furnace was recognized as an essential improvement, and has perpetuated his name as one of the pioneers in that branch of metallurgical engineering. Among his many other inventions were a continuous kiln for the production of carbon dioxide from limestone; a condensing chamber for volatile fumes; a process for treating mixed gold- and silver-ores, to recover both metals by a single operation; and a process and apparatus for smelting flue-dust and concentrates under a downward draft.

From 1895 to 1899 Mr. Brown was established at Chicago. In 1900 he became connected with the Union Iron Works at San Francisco, and he resided in that vicinity, continuing his practice as a consulting mining and mechanical engineer and his work as an inventor, until the time of his death, which occurred, however, as already noted, in Chicago. He became a member of the Institute in 1895.

*James A. Burden*, born at Troy, N. Y., January 6, 1833, was a son of Henry Burden, a noted inventor and the founder of the Burden Iron Co. He was educated at the Rensselaer Polytechnic Institute, and immediately after his graduation was placed in charge of a department of the Burden Iron Works, advancing steadily to the presidency of the company. Mr. Burden possessed the inventive talent and mechanical ability exhibited by his father. Among the many devices invented and patented by him are an electrical separator for ore, machinery for making blooms and for fettling puddling-furnaces, and especially the famous Burden machine for making horse-shoes. Mr. Burden had been an invalid for a year preceding his death. A voyage to Europe failing to restore his health, he finally submitted to an operation in abdominal surgery, which was followed by his death, September 23, 1906.

Mr. Burden had been President of the Hudson River Ore & Iron Co., and was a member of the American Society of Civil Engineers, the American Society of Mechanical Engineers, the Engineers' Club (of which he was, in 1888, the first President), the Union Club, the Union League Club, the Metropolitan Club, and several European scientific bodies. He was elected a member of the Institute in 1876, and served as Vice-President in 1880 and 1881. His interest in the young society was shown before his membership began, by the courtesy extended to it during the Troy meeting, held in 1871, the first year of its existence. The freedom with which all departments of the Burden Iron Works were then thrown open to inspection, established at that early date an invaluable precedent, the general following of which in subsequent years by the proprietors of mines, shops and works was a potent factor in the rapid growth, the prosperity and the usefulness of the Institute. At the second Troy meeting, in 1883, Mr. Burden exhibited an unlimited hospitality, socially as well as professionally, to the visiting members; and in connection with the several New York meetings, his fraternal generosity was similarly illustrated. Moreover, many of our members have individual cause to recall with gratitude his unvarying courtesy and kindness.

*George A. Crocker*, for nearly half a century the head of one of the leading firms of iron merchants in New York City, died October 20, 1906, aged 75 years. Mr. Crocker was of New England ancestry and was a graduate of Brown University. He came to New York at the age of 25, and soon afterwards, with his brother, established the firm of Crocker Brothers, which acquired and maintained for many years a leading position in the American iron trade. Mr. Crocker's business connections included the Bank of America (New York), the Virginia & Southwestern Railway Co., and the Virginia Iron, Coal & Coke Co., of each of which he was a director. Moreover, besides various other relations which he maintained in New York society, he was a vestryman of St. Bartholomew's Church, a trustee of St. Luke's Hospital, and a governor of the Metropolitan Club.

Mr. Crocker became a member of the Institute in 1879, and was a member of the Council in 1891, 1892 and 1893. Always cordial and ready in his co-operation, he rendered his greatest service in 1890, when, in connection with the meeting of the Iron and Steel Institute, held in the United States upon an invitation extended by the American Institute of Mining Engineers, he performed the arduous duties of Treasurer of the New York Finance Committee, which collected and disbursed the funds contributed by American citizens and business firms generally for the entertainment of their distinguished visitors—including, besides the visiting members of the Iron and Steel Institute, a numerous delegation from the Association of German Iron-Masters (*Verein deutscher Eisenhüttenleute*). Our Institute paid for the printing of programmes, circulars, papers and proceedings, the hire of halls, the maintenance of the headquarters Bureau of Information, etc., about \$15,000, in which sum nothing was included for social entertainments or excursions. All other items (such as the cost of two Pullman excursion trains running for a month, respectively, south as far as Alabama and northwest as far as Lake Superior, and the cost of local excursions, entertainments, souvenirs, etc.) were paid by the New York General Committee, of which Mr. Andrew Carnegie was chairman, and Mr. Crocker was treasurer, and by the local committees organized in various cities to aid this central one. The total amount raised by all these



committees was more than \$100,000; and those who, like Mr. Crocker, contributed not only money but time, thought and labor, deserved more permanent acknowledgment than they ever publicly received.

*Albert W. Fiero*, who was born Jan. 29, 1849, at Battle Creek, Mich., and died July 28, 1906, became a member of the Institute in 1886. He was one of the many distinguished American engineers, to whose loyal, though silent, support we owe so much. That his active labors were more particularly given to the American Railway Engineering and Maintenance of Way Association, the American Society for Testing Materials, and especially the Western Society of Engineers (of which he was an early and influential member), only emphasizes the fact that for more than twenty years he regarded his connection with the Institute as a privilege worth retaining, though not necessary as his only or chief professional relationship.

A sympathetic biographical notice, contributed to the *Journal of the Western Society of Engineers* (vol. xii., No. 1, Feb., 1907) by Messrs. Robert W. Hunt, Robert Forsyth (members of the Institute), and C. W. Hotchkiss, is the basis of the following account:

Mr. Fiero passed his boyhood on a farm, and gained his primary education in the schools of the vicinity. At eighteen, he obtained employment with local surveyors, and two years later, in 1869, was appointed on the civil engineering corps of the Peninsular, afterwards the Southern Michigan Railway Co., then making preliminary surveys through Michigan. With that company he remained until 1873, when he became an assistant engineer of the Chicago & Illinois River R. R. Co. In 1875 he accepted a similar position with the Chicago & Alton R. R. Co. In each of these relations, he received from his superiors strong testimonials of his ability and value.

In view of the production and rapidly growing use of Bessemer rails, Mr. Fiero entered the employ of the Vulcan Steel Co., of St. Louis, in order to learn the details of the manufacture of steel rails. The technical knowledge thus gained, combined with his previous training in practical railway-operation, equipped him to an exceptional degree for the

vitaly important work of an office then almost a novelty, though now universally recognized as a necessity; and he returned to the service of the Chicago & Alton R. R. as its rail-inspector. Subsequently, establishing his office at Joliet, Ill., he performed the same duty for other railways. In 1889 he became a member of the firm of Robert W. Hunt & Co., the operations of which, in the inspection of rails and other steel products, have received international recognition, promoted in no small degree by his high personal character, thorough practical knowledge, and an extensive personal acquaintance, which was everywhere synonymous with the enjoyment of respect and affection.

*John Herbert Fraser* was born July 24, 1870, in Manchester, England, and met his death April 1, 1906, from assassination at the hands of discontented miners at Zaruma, Ecuador, S. A. A disciplinary withholding of a shift's pay was the only assignable cause of this cowardly act—a shot from a slug-loaded shotgun in ambush, followed by knife-slashing in his head and side. Mr. Fraser was a graduate of King's College, Cambridge, and in 1897 of the Prussian School of Mines at Clausthal, Germany. In 1897–1898 he went out to the Mij Riam Kandri mines, S. E. Borneo, as engineer for the Goud-Exploratie; in the same capacity in 1898–1900 for the Mijufouw-Meatschappij, Belang, N. Celebes, and in 1900–1901 for the Mijufouw-Meatschappij, Bwool, N. Celebes—thus spending nearly four years in the Dutch East Indian possessions. In January, 1903, he became engineer and chemist for the Mazapil Copper Co., at Concepcion del Oro, Zacatecas, Mexico, where he remained about two years, going, in September, 1905, for the South American Development Co., to Guayquil, Ecuador, for a three-year engagement—tragically cut short a few months later. Mr. Fraser was a highly educated and accomplished man, of strong character, quiet fidelity, and unusual efficiency, greatly esteemed by all his associates. He joined the Institute in 1904, as a life member.

*Richard G. Hart* was born about 1839 in Cornwall, England, and died of heart-failure in the City of Mexico, November 14, 1906, after a long illness. Mr. Hart was well known in mining circles in Mexico, where he had been interested in mines

and other enterprises, especially in Sonora, including the El Tino mine, in the Altar district. He was also known in California as operating the Texas and Georgia (now the Texas Consolidated) mines at Old Diggings, Shasta county, and also the Bullyhoop and Central property in the same district. Mr. Hart had resided in California for some years before his death, but journeyed to Mexico in search of health in August, 1906. He became a member of the Institute in 1900.

*Christopher Henne* was born in Los Angeles, Cal., February 22, 1874. After attending the schools of that city and a technical school in Germany, he was graduated from Leland Stanford University, and took a post-graduate course at the School of Mines of Columbia University. His operations as a mining engineer covered a wide territory, extending from Alaska (where he prospected a year before the discovery of gold in the Klondike) to Arizona. He also traveled through Europe, Africa, Japan and China. The years from 1903 to 1906 were spent mainly in Colorado. His death occurred at Tucson, Ariz., December 12, 1906. His Institute membership dated from 1900.

*George L. Keener*, who died at Colorado Springs, August 13, 1906, after an illness of several months, was born in Iowa about 1862. On the discovery of gold at Cripple Creek he went to Colorado, where he was markedly successful and became one of the best-known mining men of the Colorado Springs district. He was superintendent of the Mary McKinney mine for several years, but resigned from that position to assume the management of the leasing-system inaugurated by the directors of the Stratton estate. He became in 1899 a member of the Institute.

*Winfield Scott Keyes* was born in 1839 at Brooklyn, N. Y., graduated at Yale College in 1860, and professionally educated as a mining engineer and metallurgist at the Royal Mining Academy of Freiberg, Saxony, whence he returned to America in 1863. For several years he pursued his profession in California, gradually extending the range of his practice to other States, Territories and countries. In the end, his practical experience of 34 years had comprised expert examinations and

mining, and metallurgical operations in California, Nevada, Montana, Colorado, Arizona, Utah, Idaho, New Mexico, Sinaloa, Durango, Sonora and Chihuahua.

In 1866 Mr. Keyes, then located as a mining engineer at Helena, Mont., contributed to the report of the U. S. Commissioner of Mining a vigorous and acute criticism\* of the U. S. mining law of 1866, including a protest against its grant of what has since become familiarly known as the "extralateral right," and an earnest recommendation of the "square location" system, under which mining rights are bounded by vertical planes through the boundaries of the claim on the surface. His position and his prophecies were justified by the subsequent history of "the law of the apex;" and he continued for nearly 40 years to urge the correction of the mistake in legislation which he had been the first to denounce.

About 1871 he went to Eureka, Nev., where he was for years the manager of the lead-silver mines and smelting-works of the Eureka Consolidated, K. K., Phoenix, Hamburg and other companies. In 1878 or 1879 he went to Leadville, Colo., where he had charge of the Chrysolite mine.

Mr. Keyes was a member of the Board of Judges of the Centennial Exposition at Philadelphia in 1876; an Honorary Commissioner to the Paris Exposition of 1878; for many years chief of the State Mining Bureau of California, and a member of the Executive Committee of the California Miners' Association. He was also general manager of the Pan-American Development Co., operating mines in Sinaloa, Mex. His published writings, aside from special professional reports, include monographs on The Resources of California and The Resources of Montana.

Mr. Keyes gave to this Institute an early and cordial support, although his residence on the Pacific slope prevented for many years his active participation in its meetings. He became a member in February, 1872, less than a year after the organization of the Institute—or, in other words, he applied for membership in it as soon as he heard of its existence. In 1880, 1881 and 1882 he served on the Council as Manager, and in

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\* *Statistics of Mines and Mining in the States and Territories West of the Rocky Mountains*, by Rossiter W. Raymond, United States Commissioner of Mining Statistics. Washington, 1869, p. 152.

1884 and 1885 as Vice-President; and in 1877 he contributed to the *Transactions* a masterly paper on the Eureka Lode of Eureka, Eastern Nevada.\*

Mr. Keyes died December 27, 1906, at San Francisco, Cal.

*John G. Lanning*, who was instantly killed in an elevator accident in Boston, July 18, 1906, had been identified with the manufacture of open-hearth steel since its beginning in this country: first at the Norway Iron Works, South Boston, Mass., and later in the operation of open-hearth plants at Birmingham and Fort Payne, Ala. The business depression of 1893 compelled the closing of the Fort Payne plant, and Mr. Lanning became furnace superintendent of the Eureka Steel Castings Co., of Chester, Pa. From 1896 to 1903 he was superintendent of the open-hearth department of the Newburg Works of the American Steel & Wire Co., at Newburg, Ohio. He resigned from this position to take charge of the Clairton Steel Works, Clairton, Pa. In 1905 he became superintendent of the Lackawanna Steel Works, Buffalo, N. Y.; and in the following year he removed to Dorchester, Mass.

Mr. Lanning was a practical designer, constructor and chemist in his department of metallurgy, and an able manager. He was a grandson of John S. Gustin, a noted designer and builder of rolling-mills, who took a prominent part in the development of the iron business of this country, and who designed and superintended the construction of the Norway Iron Works, and mills at Trenton, N. J., Worcester, Mass., and Toronto, Canada. Mr. Lanning became a member of the Institute in 1893.

*Gustavus W. Lehmann* was born in Wiesbaden, Germany, August 20, 1844, and was a pupil in chemistry of Dr. Fresenius. He came to this country in 1866; became assistant in the chemical laboratory of the Baltimore Copper Works, at Canton, in 1868, and remained until the business was suspended by the operation of the Tariff Law of 1869, which cut off its supply of foreign copper material. In 1871, when the mineral development in this country reached the point of producing sufficient copper to allow this works to resume production, he

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\* *Trans.*, vi., 344.

became its chief chemist and assayer, and remained in that position during its large development until the autumn of 1892, when, moved by the growing demand for analysis in the largely increasing fertilizer business, he began a private business as analytical chemist in Baltimore. While so engaged, he accepted the office of chemist to the city Board of Health, and continued in both until his death, in August, 1906. He was a close student in all that pertained to his chosen occupation, and kept himself well informed in its rapid progress both here and abroad. He was always a broad-minded, progressive citizen of his adopted country, taking an active interest in measures that concerned the welfare of the people. Withal, he was essentially domestic, enjoying the delightful home he had won, and cultivating its æsthetic charms.

Dr. Lehmann was a member of many organizations in and around Baltimore, and also a director in several business concerns, in all of which he was both honored and respected; and his death was a loss not only to those with whom he came in contact, but to the whole community. He became a member of the Institute in 1892.

*William H. Long* was born at Harford, Md., October 29, 1826. In 1831 his family moved to South Strafford, Vt., where his father, Daniel Long, was employed by the copper-mining company owned and conducted by Isaac Tyson, of Baltimore, Md. In 1840 another Tyson property, the Tyson Iron Co., of Plymouth, Vt., enlisted the services of Daniel Long, and the family resided there until 1844, when they removed to Point Shirley, Mass., where father and son were connected with the Revere Copper Co., the former as superintendent for many years, and the latter until 1867, when he removed to Vershire, Vt., to take charge of the property of the Vermont Copper Mining Co. He retired from this position in 1882 and settled in Fairlee, Vt., where he died, after an illness of several months, on October 27, 1906, aged 80 years. A local journal refers to him as "a kind and tender husband and friend, a genial and generous neighbor and a worthy citizen." His Institute membership began in 1882.

*Frank Chittenden Mandell* was born in Detroit, Mich., August 14, 1859. He was educated in the public schools of Detroit, and graduated in 1881 at the University of Michigan, as Bachelor of Arts. For a year or two, as member of an engineering corps of the Northern Pacific Railroad, he was engaged in field work in Minnesota, Kansas and Nebraska; and in 1883 he started for the farther West, purchasing a ticket "to the end of the line," and thus becoming a passenger on the first passenger train into Hailey, Idaho, where he established his permanent home. For two years he was associated with a local mining engineer and surveyor, and then revisited Michigan for six months of post-graduate work in engineering. On his return to Hailey he opened an office for professional practice, and engaged in mining and hydraulic engineering and mineral surveying in various parts of Idaho, Utah and Montana. His whole time, with the exception of one term in the Idaho legislature, was spent in the practice of his profession. He died December 14, 1906, of pneumonia.

Mr. Mandell was a hard student and a clear and accurate thinker, a good man and a good citizen, who left to his family and friends the precious heritage of a life well spent, an honor unsullied. His membership in the Institute dates from 1905.

*Edmund Howd Miller*, professor of analytical chemistry and assaying at Columbia University, New York City, died November 8, 1906, of typhoid fever at his home in West Nyack, N. Y. He was born in 1869 at Fairfield, Conn. In 1891 he was graduated as E. M. from the Columbia School of Mines, receiving also in 1892 the degree of A. M., and two years later that of Ph. D. From 1891 to 1894 he was assistant in assaying, was made a tutor in 1894, instructor in 1897, adjunct professor of analytical chemistry in 1901, and full professor in 1904. During the last seven years of his life he had full charge of the department of analytical chemistry at Columbia. Dr. Miller contributed largely to the literature of his department of chemistry. He was the author of *Quantitative Analysis for Mining Engineers* and of *Calculations in Analytical Chemistry*; and joint author with Dr. P. de P. Ricketts of *Notes on Assaying*; and he collaborated with E. J. Hall and M. J. Falk in the preparation of a paper on The Reduction of Lead from Litharge

in Preliminary Assays, and the Advantage of an Oxide Slag, for the New York Meeting of the Institute in 1903 (*Trans.*, xxxiv., 387-399). He also wrote many articles for scientific and technical periodicals.

Dr. Miller was chairman of the New York Division of the American Chemical Society, of which he had been Vice-President; a Fellow of the Chemical Society of London, and a member of the Executive Committee of the London Society of Chemical Industry. He joined the Institute in 1895.

*John Fossbrook Morris* was born January 1, 1879, at Breckonshire, Wales, but received his professional education at Sidney University, N. S. W., graduating in 1899 with honors as Bachelor of Engineering in the department of mining and metallurgy. From April to September of that year he was employed as assayer and draughtsman by the Long Reef Gold Mining Co., Lennonville, W. Australia. In September, 1899, he joined the Eastern Pioneer Co. as assistant engineer, and accompanied Dr. Jack on an expedition through Korea, China and Burmah, examining and reporting on mining-properties and prospects. From 1901 to 1903 he was assistant mining engineer at the Gwendoline mine, Korea, going to Australia in the following year, and to England early in 1905. In July, 1905, he went, in the employ of the Borneo Co., Ltd., to Singapore, and died, December 23, at Pahang, on the Malay Peninsula. He joined the Institute in 1903.

*Francis James Odling* was born November 12, 1845. His schooling at Highgate and at King's College, London, was supplemented by practical training at Maudsley's works, Lambeth. Pending the development of a favorable opportunity to embark in professional work, Mr. Odling engaged in the timber trade. In 1879 he became a partner in the firm of Western & Co., of Derby. This connection lasted until the concern closed up its business in 1884. In 1886 he went to Australia, stopping first at Sydney and later in the same year at Melbourne, doing metallurgical and mining work. In 1888 he became manager of the Pinnacles Tribute mine, at Broken Hill. While there he invented an electro-magnetic separator for the concentration of pyrrhotite. In 1893 he returned to Melbourne to continue his experimental work. His purpose



was to devise a magnetic separator of high intensity suitable for the separation of rhodonite and similar minerals of low magnetic permeability from the ores associated with them. His efforts resulted in the production of a type of dry magnetic separator which is said to have performed very satisfactory work. To satisfy the general preference for a wet separator, he originated one which embodied many novel ideas, and which is reported to have been very successful in operation. He was also the inventor of a new type of vanner, especially suitable for the concentration of fine slimes. Up to the time of his death he was at work on a separator to be supplied with energy from a polyphase circuit, to do away with the necessity for a mechanical drive, and was also endeavoring to make use of the alternating current in the separation of different minerals. Mr. Odling's inventions were put on the market by the Ore-Separating Co., of Melbourne. He died September 10, 1906, of pneumonia. He had joined the Institute in 1893.

*William Painter*, who died July 15, 1906, at Baltimore, was born November 20, 1838 at Triadelphia, Md., where he lived until manhood on his father's farm. After his school-days he engaged in the hide and leather business in Wilmington, Del., but a strong inclination for mechanics led him, in 1861, to select mechanical engineering as a broader field for the exercise of his remarkable inventive faculty. From that time until he died he was constantly at work on his inventions. All branches of mechanics benefited by his industry. Especially notable is a series of pumps, designed by him, many of which are extensively used both in this country and abroad. In 1882 the bottling industry attracted his notice. The idea of a bottle-stopper to be used but once and then discarded occurred to him, and led to the invention of the three systems of sealing bottles now universally used—the "loop seal," the "aluminum system" and the "crown cork." Mr. Painter also designed all the machinery for their manufacture. The Bottle Seal Co. was organized in 1882, with Mr. Painter as secretary and general manager. In 1892, when he patented the crown cork, the Crown Cork & Seal Co. was incorporated, and absorbed the Bottle Seal Co., retaining him as secretary and general manager. Mr. Painter has been termed the pioneer inventor of the bottling industry. In addition to the three systems of

sealing bottles, practically all of the machinery now used in the bottling industry was designed and patented by him or is based on his designs. More than one hundred United States patents were issued to him, and many were pending when he died. Factories for the manufacture of his devices are in operation in England, Germany, France, Japan, Mexico and Canada, as well as in this country.

A powerful physique, untiring energy, great perseverance, inventive talent and excellent business instincts, added to an attractive and generous personality, made him one of the most esteemed residents of Baltimore, in both business and social circles. He became a member of the Institute in 1893. He was also a life member of the Maryland Academy of Sciences, and a member of the American Society of Mechanical Engineers, the Merchants' and Manufacturers' Association, the Athenæum Club of Baltimore, the Baltimore Country Club, the Baltimore Yacht Club, and the Green Spring Valley Hunt Club.

*Stanley H. Pearce*, beloved and promising son of Richard Pearce, of Denver, Colo., an honored member and past-President of the Institute, died July 10, 1906, in his 38th year, after a brief but brilliant professional career. After graduation at the Sheffield Scientific School of Yale University, he began practical experience at the works of the Colorado Mining & Smelting Co., in Butte, Mont., under the immediate direction of C. W. Goodale. Upon the discovery of gold on the Klondike, he equipped and conducted an expedition to the Yukon Territory. In 1901 he engaged in copper-mining at Magdalena, Sonora, Mexico, where he was in charge of the Gayner mine when he contracted the fever which suddenly proved fatal. Mr. Pearce became a member of the Institute in 1896, and his early death disappointed many hopes, entertained not only by his distinguished father, but also by a host of his father's friends.

*Herman Poole* was born in Boston, Mass., March 9, 1849, and died February 6, 1906, at his residence in New York City. He studied, 1866-67, at the Massachusetts Institute of Technology, and, 1868-70, at Cornell University. From 1871 to 1881 he was engaged in chemical and assay work in Buffalo, N. Y., in 1876 acting as metallurgist for the Erie Mining Co., and in

1881-82 for the Alpha Oil, Gas & Mining Co., of Sarnia, Ontario, Canada. The Graselle Chemical Co., of Cleveland, Ohio, employed him as chemist from 1886 to 1891. In 1900 he was chemist and engineer for the American Gold & Copper Co., of New York, and from 1883 until the time of his death he practiced as a consulting chemist and metallurgist in that city. Mr. Poole was an able chemist, and showed his interest in his profession by membership in a number of technical societies. He joined this Institute in 1900, and contributed to its *Transactions* (xxxvi., 403) an interesting paper on Kernel-Roasting. He was also a member of the American Society of Mechanical Engineers, the American Chemical Society, the Society of Chemical Industry, and the American Electro-Chemical Society.

*Arthur Fordyce Rising* was born August 13, 1876, at Oconomowoc, Wis. His professional training was acquired at the Colorado School of Mines. After holding the position of chemist at the Raritan Copper Works, and a similar office at the De Lamar Copper Works, he became, in 1904, manager of the Madoc Mining Co., at Madoc, Canada. Later, he was occupied for some time at Tweed, Ontario, Canada, and then employed by the General Chemical Co., of New York, at Hungerford, Canada, where he had charge of mines and construction work. He died of typhoid fever at Portland, Conn., October 10, 1906. His Institute membership began in 1904.

*George H. Robinson* was born in 1854, near Cleveland, Ohio. He acquired a common school education at Akron, Ohio, and at the age of 15 years joined the office-force of Paul Brothers, civil engineers. Until 1878 he was employed in municipal- and railroad-surveying. In that year he went West as locating engineer for the Atchison, Topeka & Santa Fé Railway, on the first survey of that line into Colorado. He took up mining engineering at Leadville, in the employ of the Little Pittsburg Mining Co., and as a member of the firm of Chapman & Robinson conducted underground surveys in many of the mines of that section, including the Chrysolite, Iron Silver, and Little Chief. The United States geological survey of that district was based in large part upon the maps of mine-workings prepared by him. In 1882, after a term as assistant manager of the Chrysolite Co., he went to Montana, and was occupied on

government surveys there for two seasons, after which he engaged in coal-mine surveying and general engineering practice in Wheeling, W. Va. In 1885 he returned to Montana, becoming a member of the firm of Sizer & Robinson, of Helena. In 1886 he gave up general practice to engage with the Montana Mining Co., operating the Drumlummon mine, as engineer, soon becoming assistant manager, and, about 1890, manager. The years from 1892 to 1898 were passed in Utah and Montana, operating in the Tintic district, and managing the Mammoth Mining Co., the mining interests of Captain De Lamar, and the Utah mining properties of Franklin Farrell. In 1898 Mr. Robinson was appointed chief engineer of the Montana Ore Purchasing Co., and from 1898 to 1903 was consulting engineer to F. A. Heinze and the United Copper Co. He relinquished this position to organize the Britannia Mining Co., operating mines at Howe Sound, British Columbia, of which he became managing director. He also owned a large interest in the Yampa mine, at Bingham, Utah. His death took place July 3, 1906, in New York City. He had been connected with the Institute since 1886.

*Albert W. Sayles* was born in Quincy, Ill., May 16, 1874. His technical education was in the Mechanical Engineering Department of the Scranton (Pa.) Correspondence Schools. In 1889 he engaged with Fraser & Roberts, manufacturers of mining-machinery at Spokane, Ore., starting in the shop and becoming connected afterwards with the sales department until 1902. In 1902-3 he was assistant manager of the Eastern Oregon Mining Co., of Bourne, Ore.; from 1903 to October, 1905, the agent of the Mine & Smelter Supply Co. in north-western territory, with headquarters in New York, N. Y. At the last-mentioned date he went to Carbo, Sonora, Mexico, for the Giroux Consolidated Mines Co.

On January 9, 1906, Mr. Sayles left the company's Sultana mines for Carbo, but did not arrive as expected. Search on the trail discovered his horse without saddle, and portions of his body. He was supposed to have been murdered by Yaqui Indians, some of whom had been seen near the trail. Although a reward was offered for the capture of the murderers, no further trace was found. Mr. Sayles was elected a member of the Institute in May, 1905.

*Richard John Seddon* was born in Lancashire, England, in 1841. His first employment was as apprentice to an engineer. In 1863 he emigrated to Australia, where he became a merchant. When the "gold-fever" broke out, he engaged in mining at Bendigo. A few years later he went to New Zealand, where he worked as a miner and mining engineer. He acquired prominence as a labor-leader, and in 1879 he was elected to the Legislature, where he soon came to the front, being made Minister of Mines in 1891 and Prime Minister in 1893, which latter office he held until his death. Mr. Seddon was a man of high courage, great energy and inflexible determination, who worked his way to the head of the government of his adopted country and held his place by his commanding personality. Under his administration, New Zealand took the lead in the enactment of laws for the promotion of the welfare of the working-class. Compulsory arbitration of industrial disputes, old-age pensions, universal suffrage for both sexes, the living wage, State-owned railways, telegraphs and telephones, postal savings-banks, loans to settlers, a land-purchase system to enforce the division of large land-holdings, and many other measures designed to enhance the prosperity of the people, have earned for New Zealand the name of "the workingman's paradise." The remarkable demonstrations of grief on the occasion of the funeral of the late Premier testify to the place he held in the affections of the people. Business was generally suspended throughout the country on the day of the funeral. Mr. Seddon died June 10, 1906, on board the steamer on which he had embarked a few hours before at Sydney, N. S. W., to return to New Zealand after a visit to Australia. He became a member of the Institute in 1888.

*James C. Simpson*, well known in the West as a colliery operator and manager, was born in Scotland, where (after a preliminary education and experience, of which the particulars have not been furnished for this notice) he became general manager for his uncle, George Simpson, who had opened coal-seams at Hamilton. This position he retained under the succeeding owners of the property, until, two or three years after 1880, he left Hamilton to engage in wider operations connected with the coal-trade of both England and the United States, operating extensively in both countries. From 1886 to 1898

he was general manager of the Consolidated Coal Co., of St. Louis, Mo.; but in the latter year he returned to Scotland and settled in Edinburgh, where he died, September 9, 1906, of heart-failure.

He was one of the original members, and in 1879 the Vice-President, of the Mining Institute of Scotland, the *Transactions* of which for that year contain a valuable paper by him on The Ventilation of Mines, Economically Considered. He became a member of this Institute in 1887, and continued his connection with it, even through the final years of his retirement and inaction, until he died.

*Francis Lewis Sperry* was born in Tallmadge, Ohio, October 22, 1861, and died in that place, April 17, 1906. After graduating at the Tallmadge high school, he took, 1883-4 to 1885-6, a special course in chemistry and metallurgy at the Sheffield Scientific School of Yale University. Upon leaving New Haven, he became chief chemist for the Canadian Copper Co., at Sudbury, Ontario, Canada, where he remained until 1891. While in this employ he discovered in the nickel-bearing pyrrhotite and chalcopyrite of Sudbury the only known native ore of platinum, an arsenide, which, in his honor, has been named sperrylite. From Canada he went to Freiberg, Saxony, for further study; and after his return, practiced, 1896-9, as consulting chemist in New York City. In 1900 Mr. Sperry returned to his early home in Ohio, where he continued expert chemical and metallurgical work, though hampered and distracted by business cares and litigations, imposed upon him as the representative of his family.

Mr. Sperry was a devoted member of the Institute, which he joined in 1889. In 1895 he contributed to the *Transactions* (xxv., 51) a notable paper on Nickel and Nickel Steel.

*John Stanton* was born in Bristol, England, February 25, 1830, and died in New York City, February 23, 1906. His father, John Stanton, was a civil and mining engineer, and came to this country with his family in 1835, locating himself at Pottsville, Pa., where he bought coal-lands and engaged in coal-mining. From him his son received instruction in engineering, and, about 1847, at the age of 17, took charge of

and other enterprises, especially in Sonora, including the El Tino mine, in the Altar district. He was also known in California as operating the Texas and Georgia (now the Texas Consolidated) mines at Old Diggings, Shasta county, and also the Bullychoop and Central property in the same district. Mr. Hart had resided in California for some years before his death, but journeyed to Mexico in search of health in August, 1906. He became a member of the Institute in 1900.

*Christopher Henne* was born in Los Angeles, Cal., February 22, 1874. After attending the schools of that city and a technical school in Germany, he was graduated from Leland Stanford University, and took a post-graduate course at the School of Mines of Columbia University. His operations as a mining engineer covered a wide territory, extending from Alaska (where he prospected a year before the discovery of gold in the Klondike) to Arizona. He also traveled through Europe, Africa, Japan and China. The years from 1903 to 1906 were spent mainly in Colorado. His death occurred at Tucson, Ariz., December 12, 1906. His Institute membership dated from 1900.

*George L. Keener*, who died at Colorado Springs, August 13, 1906, after an illness of several months, was born in Iowa about 1862. On the discovery of gold at Cripple Creek he went to Colorado, where he was markedly successful and became one of the best-known mining men of the Colorado Springs district. He was superintendent of the Mary McKinney mine for several years, but resigned from that position to assume the management of the leasing-system inaugurated by the directors of the Stratton estate. He became in 1899 a member of the Institute.

*Winfield Scott Keyes* was born in 1839 at Brooklyn, N. Y., graduated at Yale College in 1860, and professionally educated as a mining engineer and metallurgist at the Royal Mining Academy of Freiberg, Saxony, whence he returned to America in 1863. For several years he pursued his profession in California, gradually extending the range of his practice to other States, Territories and countries. In the end, his practical experience of 34 years had comprised expert examinations and

mining, and metallurgical operations in California, Nevada, Montana, Colorado, Arizona, Utah, Idaho, New Mexico, Sinaloa, Durango, Sonora and Chihuahua.

In 1866 Mr. Keyes, then located as a mining engineer at Helena, Mont., contributed to the report of the U. S. Commissioner of Mining a vigorous and acute criticism\* of the U. S. mining law of 1866, including a protest against its grant of what has since become familiarly known as the "extralateral right," and an earnest recommendation of the "square location" system, under which mining rights are bounded by vertical planes through the boundaries of the claim on the surface. His position and his prophecies were justified by the subsequent history of "the law of the apex;" and he continued for nearly 40 years to urge the correction of the mistake in legislation which he had been the first to denounce.

About 1871 he went to Eureka, Nev., where he was for years the manager of the lead-silver mines and smelting-works of the Eureka Consolidated, K. K., Phoenix, Hamburg and other companies. In 1878 or 1879 he went to Leadville, Colo., where he had charge of the Chrysolite mine.

Mr. Keyes was a member of the Board of Judges of the Centennial Exposition at Philadelphia in 1876; an Honorary Commissioner to the Paris Exposition of 1878; for many years chief of the State Mining Bureau of California, and a member of the Executive Committee of the California Miners' Association. He was also general manager of the Pan-American Development Co., operating mines in Sinaloa, Mex. His published writings, aside from special professional reports, include monographs on The Resources of California and The Resources of Montana.

Mr. Keyes gave to this Institute an early and cordial support, although his residence on the Pacific slope prevented for many years his active participation in its meetings. He became a member in February, 1872, less than a year after the organization of the Institute—or, in other words, he applied for membership in it as soon as he heard of its existence. In 1880, 1881 and 1882 he served on the Council as Manager, and in

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\* *Statistics of Mines and Mining in the States and Territories West of the Rocky Mountains*, by Rossiter W. Raymond, United States Commissioner of Mining Statistics. Washington, 1869, p. 152.



1884 and 1885 as Vice-President; and in 1877 he contributed to the *Transactions* a masterly paper on the Eureka Lode of Eureka, Eastern Nevada.\*

Mr. Keyes died December 27, 1906, at San Francisco, Cal.

*John G. Lanning*, who was instantly killed in an elevator accident in Boston, July 18, 1906, had been identified with the manufacture of open-hearth steel since its beginning in this country: first at the Norway Iron Works, South Boston, Mass., and later in the operation of open-hearth plants at Birmingham and Fort Payne, Ala. The business depression of 1893 compelled the closing of the Fort Payne plant, and Mr. Lanning became furnace superintendent of the Eureka Steel Castings Co., of Chester, Pa. From 1896 to 1903 he was superintendent of the open-hearth department of the Newburg Works of the American Steel & Wire Co., at Newburg, Ohio. He resigned from this position to take charge of the Clairton Steel Works, Clairton, Pa. In 1905 he became superintendent of the Lackawanna Steel Works, Buffalo, N. Y.; and in the following year he removed to Dorchester, Mass.

Mr. Lanning was a practical designer, constructor and chemist in his department of metallurgy, and an able manager. He was a grandson of John S. Gustin, a noted designer and builder of rolling-mills, who took a prominent part in the development of the iron business of this country, and who designed and superintended the construction of the Norway Iron Works, and mills at Trenton, N. J., Worcester, Mass., and Toronto, Canada. Mr. Lanning became a member of the Institute in 1893.

*Gustavus W. Lehmann* was born in Wiesbaden, Germany, August 20, 1844, and was a pupil in chemistry of Dr. Fresenius. He came to this country in 1866; became assistant in the chemical laboratory of the Baltimore Copper Works, at Canton, in 1868, and remained until the business was suspended by the operation of the Tariff Law of 1869, which cut off its supply of foreign copper material. In 1871, when the mineral development in this country reached the point of producing sufficient copper to allow this works to resume production, he

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\* *Trans.*, vi., 344.

became its chief chemist and assayer, and remained in that position during its large development until the autumn of 1892, when, moved by the growing demand for analysis in the largely increasing fertilizer business, he began a private business as analytical chemist in Baltimore. While so engaged, he accepted the office of chemist to the city Board of Health, and continued in both until his death, in August, 1906. He was a close student in all that pertained to his chosen occupation, and kept himself well informed in its rapid progress both here and abroad. He was always a broad-minded, progressive citizen of his adopted country, taking an active interest in measures that concerned the welfare of the people. Withal, he was essentially domestic, enjoying the delightful home he had won, and cultivating its æsthetic charms.

Dr. Lehmann was a member of many organizations in and around Baltimore, and also a director in several business concerns, in all of which he was both honored and respected; and his death was a loss not only to those with whom he came in contact, but to the whole community. He became a member of the Institute in 1892.

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and civil engineer of the Cochita Gold Mining Co., Bland, New Mexico, and afterwards had charge of the cyanide department of that company. He was next employed at Pitkin, Colo., as superintendent of the Wallace Mining Co., after which he went to Mexico as superintendent of the Yerbabuena Mining Co., and held that office until his decease. His Institute membership dates from 1900.

*John Price Wetherill* was born in 1844 at Belleville, N. Y., and died November 9, 1906, at his home in Philadelphia. His father, Samuel Wetherill, who founded the Lehigh Zinc Works at South Bethlehem (once called Wetherill), and conducted it up to the outbreak of the Civil War, when he retired from its management to enter the Union Army, was the inventor of a process for making zinc oxide direct from the ore, which revolutionized a large department of the metallurgy of zinc. John P. Wetherill was a graduate in mining engineering of the Polytechnic College, Philadelphia. He established himself as a consulting engineer at Mahanoy City, and after a short time became resident engineer of the Reading Coal & Iron Co. at Tremont, and later at Pottsville, Pa., having full charge of all the collieries of that company. In 1881 he resigned this charge to become general manager of all the plants and properties of the Lehigh Zinc Co., South Bethlehem, Pa., of which he was one of the founders and incorporators, and which had just purchased the Lehigh Zinc Works, founded by his father. In 1897 the company was absorbed by the New Jersey Zinc Co. At that time Mr. Wetherill retired from active supervision, continuing as consulting engineer and one of the directors until about a year before his death.

Mr. Wetherill had a world-wide reputation as an expert in all departments of the zinc industry. He devoted years to research in his special field, and devised many improvements in processes and practice. His best-known invention, the Wetherill magnetic separator, which is in use in many parts of the world, is described in a paper by Messrs. Wilkins and Nitze on The Magnetic Separation of Non-Magnetic Material, *Trans.*, xxvi., 851, and the discussion thereof, *Trans.*, xxvi., 1089. Mr. Wetherill became a life member of the Institute in 1896.

## Relative Elimination of Iron, Sulphur, and Arsenic in Bessemerizing Copper-Mattes.

A Discussion of the Paper of E. P. Mathewson, presented at the New York Meeting, April, 1907, and printed in *Bi-Monthly Bulletin*, No. 13, January, 1907, pp. 7 to 14.

PROF. HENRY M. HOWE, New York, N. Y. (communication to the Secretary \*):—The results presented in Mr. Mathewson's paper are of very great interest. Perhaps the most interesting is that shown in Table I. and Fig. 1, in which the arsenic decreases in 10 min. from 0.22 to 0.07 per cent. This is such a large decrease that it is to be hoped that Mr. Mathewson will verify it by repeating his tests with a matte of similar composition. This is particularly to be desired, because the simultaneous removal of sulphur appears to be very small. All three blows further agree in showing that the removal of arsenic is in the very early part of the blow. The fact that the removal of arsenic then ceases abruptly cannot be explained completely by the fact that the arsenic has fallen so low as by its lowness to resist further removal, because in the first blow the arsenic becomes stationary at 0.06 per cent., whereas in the third blow it does not become stationary until it has fallen to 0.034 per cent. The abrupt ending of the removal of arsenic is more likely to find its explanation in the composition of the slag, and it is to be hoped that Mr. Mathewson will supplement these extremely valuable data with others in which the composition of the slag at the same time shall be given.

The sudden rise of arsenic toward the end of the third blow I suppose must be referred to an error in sampling or analysis.

Mr. Mathewson speaks on page 14 of the "percentages of iron . . . volatilized during the first period." Is it his meaning that all this iron is really volatilized, or does he mean that the iron is scorified and the sulphur volatilized?

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\* Received Feb. 9, 1907.

E. P. MATHEWSON (communication to the Secretary\*) :—  
Referring to the final paragraph of Prof. Howe's discussion, I  
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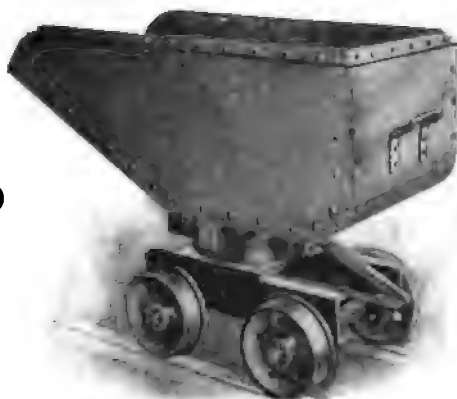
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## MINE CARS, WHEELS AND AXLES

SCOOP

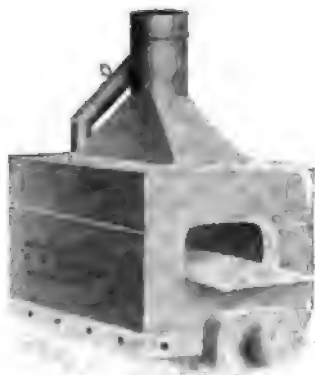


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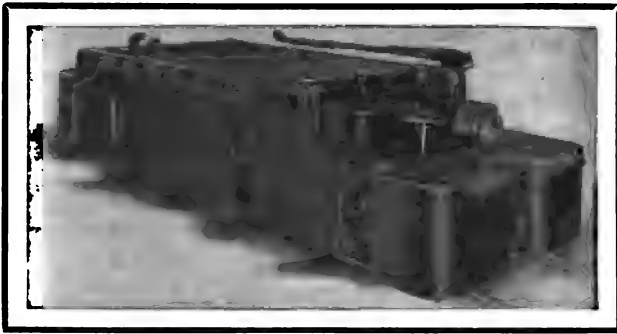
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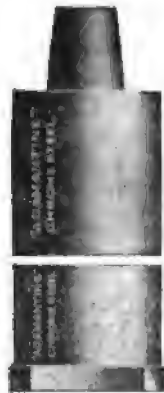
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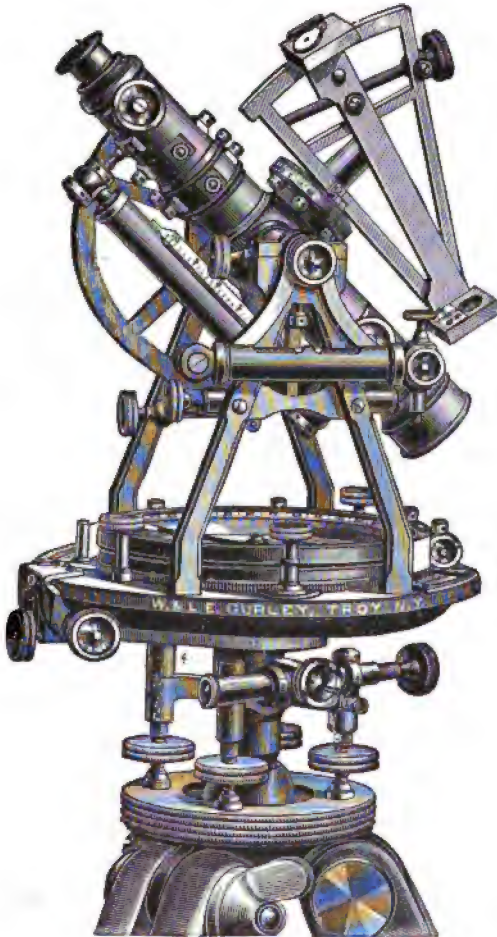
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SEPTEMBER.

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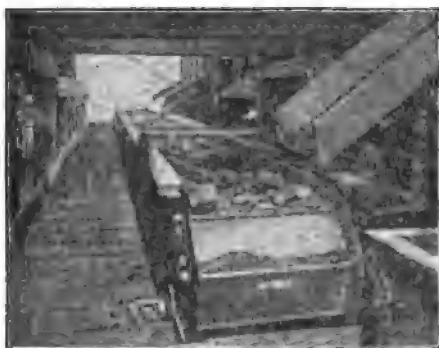
PUBLISHED BY THE AMERICAN INSTITUTE OF MINING ENGINEERS

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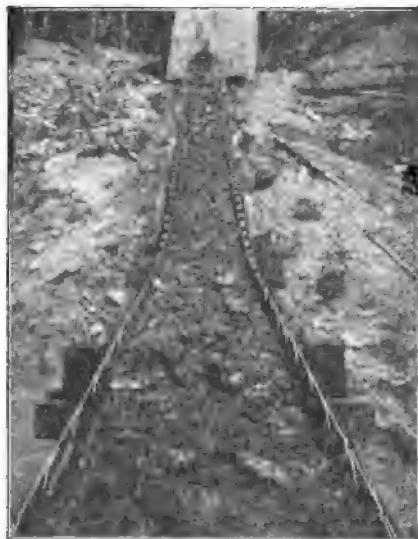
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Having recently spent more than a week at Jamestown, in the capacity of a Juror of Awards, Division of Mines and Metallurgy, I wish to assure the members of the Institute, notwithstanding the conflicting and sometimes discouraging reports of newspaper correspondents, that the Exposition is well worth a visit, even from those who remember Chicago, Buffalo, St. Louis, and Portland. Its smaller area will be to many an additional attraction; its pleasing colonial architecture has a distinctive charm, not derived by mere imitation from previous examples; and, above all, the mineral exhibits in the Mines Building are so varied and so interesting as almost to warrant a journey on their sole account.

With regard to convenient and comfortable lodgings, etc., I shall be glad to answer inquiries from members contemplating this trip.

**JOSEPH STRUTHERS,**  
*Assistant Secretary.*

**SEPTEMBER 23, 1907.**



# BI-MONTHLY BULLETIN

OF THE

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No. 17	SEPTEMBER	1907
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PUBLISHED BY THE AMERICAN INSTITUTE OF MINING ENGINEERS

At S-W. Cor. of Seventh and Cherry Streets,

PHILADELPHIA, PA.

Editorial Office at 29 West 39th St., New York, N. Y.

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*Subscription (including postage), \$10 per annum; to members of the Institute, public libraries, educational institutions and technical societies, \$5 per annum.*

*Single copies (including postage), \$2 each; to members of the Institute, public libraries, etc., \$1 each.*

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# TABLE OF CONTENTS.

## SECTION I. INSTITUTE ANNOUNCEMENTS.

	PAGE
Bi-Monthly Bulletin, . . . . .	iii
Jamestown Exposition, . . . . .	iii
List of Officers for the Year Ending February, 1908, . . . . .	iv
Collective Index of the <i>Transactions</i> , Vols. I. to XXXV., inclusive, . . . . .	v
Library, . . . . .	xi
Membership, . . . . .	xix
Candidates for Membership, . . . . .	xxi
Change of Address of Members, . . . . .	xxiii
Address Wanted, . . . . .	xxxv

## SECTION II. TECHNICAL PAPERS.

No. 1. E. VON MALTITZ. Blow-Holes in Steel Ingots, . . . . .	691
No. 2. J. KENT SMITH. The Present Source and Uses of Vanadium, . . . . .	727
No. 3. RICHARD W. LODGE. The Effect of High Litharge in the Crucible-Assay for Silver, . . . . .	733
No. 4. JOHN J. PORTER. Zinc-Oxide in Iron-Ores, and the Effect of Zinc in the Iron Blast-Furnace, . . . . .	739
No. 5. A. L. SWEETSER. Chlorination of Gold-Ores; Laboratory Tests, . . . . .	747
No. 6. WOOLSEY MCA. JOHNSON. Physical Factors in the Metallurgical Reduction of Zinc Oxide, . . . . .	757
No. 7. ALFRED C. LANE and HENRY M. HOWE. Discussion of Mr. Howe's Paper, Piping and Segregation in Steel Ingots, . . . . .	765
No. 8. ALBERT HILL FAY. Geology and Mining of the Tin-Deposits of Cape Prince of Wales, Alaska, . . . . .	769
No. 9. EDWARD A. PARKER. Coal-Briquetting in the United States, . . . . .	789
No. 10. THOMAS LEONARD WATSON. The Occurrence of Nickel in Virginia, . . . . .	829
No. 11. T. F. WITHERBEE. Supplementary Note: Blast-Furnace Practice, . . . . .	845
No. 12. PROCEEDINGS OF THE NINETY-THIRD MEETING, TORONTO, JULY, 1907, . . . . .	847

## ERRATA.

Correction to *Bi-Monthly Bulletin*, No. 16, July, 1907:

Page vi., line 34. For "Depomuceno" read "Nepomuceno."

## BI-MONTHLY BULLETIN.

### SECTION I.—INSTITUTE ANNOUNCEMENTS.

This section contains announcements of general interest to the members of the Institute, but not always of sufficient permanent value to warrant republication in the volumes of the *Transactions*.

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### SECTION II.—TECHNICAL PAPERS AND DISCUSSIONS.

[The American Institute of Mining Engineers does not assume responsibility for any statement of fact or opinion advanced in its papers or discussions.]

A detailed list of the papers contained in this section is given in the Table of Contents. They have been so printed and arranged (blank pages being left when necessary) that they can be separately removed for classified filing, or other independent use.

A small stock of separate pamphlets, duplicating the technical papers given in Section II. of this Bulletin, is reserved for those who desire extra copies of any single paper.

Comments or criticisms upon all papers given in this section, whether private corrections of typographical or other errors or communications for publication as "Discussions," or independent papers on the same or a related subject, are earnestly invited.

All communications concerning the contents of this Bulletin should be addressed to Dr. Joseph Struthers, Assistant Secretary and Editor, 29 W. 39th St., New York City (Telephone number 4600 Bryant).

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### JAMESTOWN EXPOSITION.

See Special Notice, accompanying this number, concerning the Headquarters established for the Institute at the Jamestown Exposition through the courtesy of Dr. Joseph Hyde Pratt, Mem. A. I. M. E., Chief of the Department of Mines and Metallurgy.

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\* SECRETARY'S NOTE.—The Council is the professional body, having charge of the election of members, the holding of meetings (except business meetings), and the publication of papers, proceedings, etc. The Board of Directors is the body legally responsible for the business management of the Corporation, and is therefore, for convenience, composed of members residing in New York.

**COMPLETE ANALYTICAL AND ALPHABETICAL INDEX OF VOLS. I.—XXXV.,  
INCLUSIVE, OF THE TRANSACTIONS OF THE INSTITUTE.**

The following preface to the forthcoming complete analytical and alphabetical index of Vols. I. to XXXV., inclusive, of the *Transactions*, is here published in advance, as likely to be interesting and suggestive to non-members, as well as to members, of the Institute :

The great additional value given to professional books by adequate alphabetical and analytical indexes has been recognized from the beginning in the publication of the *Transactions* of the American Institute of Mining Engineers. The first ten volumes, edited by Dr. Thomas M. Drown, the secretary, were provided with indexes, as well as tables of contents. Moreover, he included in Vol. V. (published in 1877), a consolidated index of Vols. I. to V., inclusive; and, at the time of his resignation, in 1884, he had prepared a similar index of Vols. I. to X., inclusive, which was published in the following year.

The indexes of the annual volumes from Vol. XI. on were made much more extensive than their predecessors. Casual mentions, as well as important discussions, were included; the geographical localities of mines or works alluded to in the text were added in the index; and numerous cross-references were introduced, with the purpose of making it easy for the student to discover at once what the *Transactions* contained, either of thorough treatment or of hints and clues to further inquiry, concerning any topic, locality, or person within their scope. In order to extend the advantages of this larger scheme to the earlier volumes, a consolidated index of Vols. I. to XV., inclusive (published in 1888), was prepared by compiling the several annual indexes, and introducing additional items for those preceding Vol. XI. Vol. XX., issued in 1892, contained a similar consolidated index for Vols. XVI. to XX., inclusive; in

1897, a separate index-volume, covering Vols. XXI to XXV., inclusive, was published, and in 1902 appeared another, for Vols. XXVI. to XXX. These four indexes, for Vols. I. to XV., XVI. to XX., XXI. to XXV., and XXVI. to XXX., respectively, bound together into a book of about 950 octavo pages, have constituted for the last five years a consolidated index to the *Transactions* which they cover—with the single difference that the book had to be consulted four times, where a single comprehensive index would require to be consulted but once. This disadvantage, however, was relatively small, compared with the great convenience of finding by four trials in one book what would otherwise call for 30 separate searches in 30 books. Moreover, the possession of the one might be most useful to a student who did not possess the 30, by indicating to him what they contained, and thus enabling him to make further inquiry without fruitless labor. To this feature of value in such indexes, I shall presently recur.

The usefulness of the compound four-fold index referred to, is proved by the fact that the supply of copies has been exhausted. In view of this foreseen event, it was decided to issue, instead of the customary additional five-year index, a complete consolidated index of Vols. I. to XXXV., inclusive, which should take the place of all preceding ones; and Miss L. E. Howard, the accomplished and indefatigable librarian of the Institute, has been for more than two years engaged, with competent assistance, upon this laborious task. The result, embodying a compilation of the former index volumes and the annual indexes of Vols. XXXI. to XXXV., inclusive, with numerous corrections, improvements in classification, additional cross-references, etc., is the present book, concerning which I desire to offer the following comments:

1. That this Index is absolutely free from error, it would be ridiculous to assert. The atmosphere of an office and library crowded with daily visitors and overwhelmed with daily routine work does not permit such careful, intense, and minute revision as technical perfection requires. While many errors contained in our former indexes have been detected and corrected in this one, some have doubtless been brought forward into it. In this respect, I beg (though I hope it is unnecessary) to say, that with regard to this, as to every other publication of the Insti-

tute, our rule and practice is to be grateful, not annoyed, when we receive notice of an error, and to acknowledge and correct, not hide or ignore it. Notice of any errors discovered in this book is therefore earnestly requested.

2. It would be likewise unwarrantable to claim for the present Index a complete and consistent logical arrangement. Indeed, I am disposed rather to assert for it a higher merit—namely, that of a method more elastic than any fixed system. The controlling purpose has been to make sure that the reader, seeking either the name of a mine or process, or the forgotten title of a paper or its author, or, on the other hand, desiring to be put upon the track of an inquiry concerning something which may or may not be mentioned in the *Transactions*, and wishing to be positively assured as to that point, before looking elsewhere, shall be satisfied as quickly as possible. Hence, in the construction of our index, we put ourselves in the reader's place, and often introduce a cross-reference not logically required by the text, because it may help him, if he has forgotten the term actually employed in the *Transactions*. In short, we make the index, not a mere concordance of words, but also a dictionary of topics and ideas. And, as to any proposed cross-reference, our rule is, "When in doubt, put it in!" For it cannot harm anybody, and it may help somebody.

The result of this system, if system it can be fairly called, has been, I know, that many members of the Institute have formed the habit of going first of all to the Index of our *Transactions*, sure of learning at once, and without troublesome search, whether and to what extent these volumes can aid them in any investigation they are called to make. I need not emphasize the folly of publishing, in these days, books on technical subjects without alphabetical indexes—a sin for which the most elaborate table of contents does not atone, and which, having repeatedly brought its own punishment, has well nigh gone out of fashion, as unprofitable sins are wont to do. But I may be permitted to express my surprise that so many editors and publishers of books intended for permanent reference, having taken the trouble to make indexes, do not take the small further trouble of making them adequately, abundantly—even unnecessarily and ostentatiously—full. There is no better recommendation of such a book to the potential pur-

chaser, because there is no equal guaranty of its continued value to the actual purchaser. Practical men look to books for aid in the form of energy given or saved to them. Now  $mv^2$  is the formula for energy; and in this case  $m$  is the information wanted, and  $v$  is the speed with which it can be obtained. In other words,  $m$  represents the value of the text of a book, and  $v$  the effective aid furnished by the index; so that the permanent usefulness of the book is represented by the text, multiplied by the square of the index! This may be questionable mathematics, but it is unquestionable experience, as the practice of nearly half a century qualifies me to declare.

3. Comparatively few of the members of this Institute possess complete sets of its *Transactions*. The number of such complete sets remaining on hand is very small indeed. The volumes have never been stereotyped, and it is not likely that any of them will be reprinted. The Institute maintains, at more than a hundred important mining centers throughout the world, free sets of its *Transactions*, open for consultation without fee, to all suitable applicants. This list cannot well be increased. If this new consolidated Index of 35 volumes would be useful only to those who possess, or may hereafter possess, all of those volumes, the large cost of its preparation and publication would involve a most unwarranted and foolish outlay. I wish, therefore, to urge upon all students and practitioners, whether members of the Institute or not, the following considerations concerning the special value of this Index to those who have not the volumes themselves.

Indeed, in a certain sense, such an index is more useful to the non-possessor than to the possessor of the books. For the latter can, at the cost of some extra labor, find out what each volume contains, whereas the former, having at hand neither books nor index, is utterly ignorant whether the *Transactions* could help him or not. I often receive letters from members thus situated, inquiring what our *Transactions* contain on this or that subject; and while I do my best to satisfy them, I cannot be sure that my hasty search is complete and conclusive; and I am obliged, whenever practicable, to refer them to some library containing the volumes, and bid them do their own hunting. But, on the contrary, if a member, finding in the Index the title of a paper, or the record of any remarks, con-

cerning a subject in which he is interested, writes to the Secretary concerning it, I can easily, and always do gladly, tell him in reply what is the nature, length, etc., of the said passage; whether we can furnish it to him in separate pamphlet form, etc.—these being particulars which my clerks can ascertain for me at once. Moreover, members of the Institute send me, not infrequently, valuable professional papers, in which previous contributions to the *Transactions*, directly or indirectly dealing with the same subjects, are ignored. It is my theory that the author of an Institute paper should recognize what his fellow-members have done before him in the same line. Of course, if he fails to do this, it is because he does not possess the back-volumes of our *Transactions*, and is not acquainted with their contents. It is the duty of the Secretary to call his attention to this omission; and the result is not only extra labor for the Secretary, but often also some unnecessary mortification to the author, who is obliged to recast his paper in the light of the new information furnished to him. All this would be avoided, if the author had at hand simply an Index of the *Transactions*, upon the consultation of which he could have obtained from the Secretary, in advance, both guidance and aid.

4. But there is another and more important reason for recommending to all mining engineers, metallurgists, etc., whether members of the Institute or not, the acquisition of this volume. Namely, the issue of it by the Institute is part of a plan, the full realization of which is scarcely yet in sight, while every step towards its complete accomplishment is, in my judgment, to be regarded as an essential gain.

As is well-known, the generosity of Mr. Andrew Carnegie, for many years a member, and now an honorary member, of this Institute, has provided for the Institute, together with the American Society of Mechanical Engineers and the American Institute of Electrical Engineers, the magnificent building in which our headquarters are now permanently located. One consequence of this arrangement is that the libraries of the three societies are accommodated together in the 12th and 13th stories of the building. These libraries, aggregating more than 50,000 books, pamphlets, etc., comprise perhaps the best record of modern engineering practice in the departments of the three



societies which can be found in the United States—for specifically American practice, perhaps the best in the world. At the present time, they are separately owned and administered by the three societies ; but, so far as their use is concerned they constitute practically one library, to which the members of each society, and others properly introduced, have free access. We hope, by means of indexes and catalogues, to extend this advantage to members at a distance, who may thus be enabled to consult books and periodicals by correspondence, to obtain copies of text and drawings, etc. Towards this end, the issue of the present Index is an important step.

5. Finally, this volume has not been stereotyped ; the edition is limited to 1,600 copies ; and orders received will be filled in succession, according to their dates, while the supply lasts.

## LIBRARY.

### RULES.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

AMERICAN INSTITUTE OF MINING ENGINEERS.

Open on all week days from 9 a.m. to 5 p.m. Only members of the above Societies, and others duly introduced by the Secretary or other authorized officer of one of those Societies, will be permitted access to the alcoves or other spaces inside the rail.

For the protection and convenience of members, the following rules have been adopted :

The Secretary of each Society will, upon application, issue to any member of his Society in good standing a personal, non-transferable card, entitling him to the use of the Libraries in the alcoves of the Reading Room.

This card, as well as any card of introduction given to a non-member, must be signed by the person receiving it, and surrendered at the desk at the time of its presentation. At every visit he must identify himself by signing his name in the registry.

The above rules apply to all persons except officers of the three Societies, personally known as such to the librarians.

The librarians are not permitted to lend to any person any catalogued pamphlet or volume, unless authorized in writing so to do by the Secretary or Chairman of the Library Committee of the Society to which the pamphlet or volume belongs.

Any person discovering a mutilation or defect in any book of the libraries is requested to report it to the librarian on duty.

It is the earnest desire of the Library Committee to complete the files of the more important serial publications in the library of the American Institute of Mining Engineers, and for the furtherance of this wish, the co-operation of members and friends of the Institute is respectfully invited. Early volumes of the following are needed :

**American Chemical Society.**  
**American Foundrymen's Association.**  
**Australian Mining Standard.**  
**Chemical Society of London.**  
**Deutsche Chemische Gesellschaft.**  
**The Foundry.**  
**New Zealand Mines Record.**  
**Queensland Government Mining Journal.**  
**La Revue Universelle des Mines.**  
**Société Chimique de Paris.**  
**Société de L'Industrie Minérale.**  
**Stahl und Eisen.**  
**Tonindustrie Zeitung.**  
**Zeitschrift für Anorganische Chemie.**  
**Zeitschrift für Angewandte Chemie.**

Complete sets of the above publications are greatly needed, as none of them are duplicated in the library of the American Institute of Electrical Engineers or that of the American Society of Mechanical Engineers.

If any one can supply back volumes, please communicate, stating terms of offer, to R. W. Raymond, Chairman of the Library Committee, 29 W. 39th St., New York, N. Y.

#### **Accessions.**

From July 1 to August 31, 1907.

##### **H. Altman.**

N. Y. STATE—LEWIS AND CLARKE EXPOSITION COMMISSION.  
*New York at the Lewis and Clarke Exposition.* 127 p.  
por. pl. 4to. Albany, 1906.

##### **Mr. Beeler.**

WYOMING—STATE GEOLOGICAL SURVEY. *Mining Laws of Wyoming.* 12mo. Cheyenne, 1907.

##### **Blakiston's Son & Co., Philadelphia, Pa.**

ALLEN, A. H. *Commercial Organic Analysis.* Edition 3,  
vol. 2, pt. 2. 8vo. Philadelphia, 1907.

[**SECRETARY'S NOTE.**—The well-known and highly esteemed treatise of which this book forms a part comprises eight octaves, which might be called volumes, but that the author employed that term in a different sense, so as to have but four "volumes," of which the second and third occupy each three books, called "Parts." It would have been better to reverse the nomenclature, and treat the subject in "Parts," with "Volumes" as the subordinate divisions. But that is a small matter. Much more important is the circumstance that with the issue of this "Part" the complete treatise is now again available in revised and modernized form.

The author, an experienced and distinguished English analyst, contributed much conscientious and skillful labor to the second and third editions of his great work; but his lamented and too early death in 1904 defeated his hope of completing the latest edition. Other parts of it were perfected with the aid of Dr. Henry Leffman and Prof. J. Merritt Matthews, of Philadelphia; and the part here under notice, upon the revision of which Mr. Allen had been at work since 1898, has been finished, in part by Dr. Leffman, but mainly by the author's personal friend and co-worker, Mr. Tankard, himself an expert of no mean standing, who has independently contributed to it the articles on the analysis of caoutchouc, guttapercha and their substitutes, and on the individual essential oils and the terpenes oils. The contents of the book comprise, of the aromatic acids, the sulphonated phenols and their allies; benzoic and cinnamic acid, with their derivatives; salicylic acid, the dihydroxy-benzoic acids, and gallic acid, with their allies; and the phthalic acids. The resins and turpentine follow; and the volatile or essential oils conclude the book. Following these, is a valuable table of all the better-known essential oils (210 in number), giving, with regard to each, so far as possible, the chief sources of supply, the percentage of the oil yielded by the raw material, the specific gravity, optical rotation-test and other characters, the known constituents and the medical or commercial uses. There is a good index at the end of all.—R. W. R.]

### **Board of Rapid Transit Commissioners.**

N. Y.—RAPID TRANSIT COMMISSION. *Report of the Commissioners*, 1907.

### **Bennett H. Brough.**

IRON AND STEEL INSTITUTE. *Transactions*, 1869. 12mo. London, 1907. (Reprint.)

### **California State Mining Bureau.**

CALIFORNIA—STATE MINING BUREAU. *General Index to State Publications*. 54 p. 8vo. Sacramento, 1907. (*Bulletin* No. 46.)

### **Connecticut State Library.**

CONNECTICUT—STATE GEOLOGICAL AND NATURAL HISTORY SURVEY. *Bibliography of the Geology of Connecticut*. 123 p. 8vo. Hartford, 1907. (*Bulletin* No. 8.)

### **Engineering and Mining Journal.**

HANAL, DR. RUDOLF. *Jahrbuch der Oesterreichischen Berg- und Hüttenwerke, Maschinen- und Metallwarenfabriken*. 1906. 12mo. Wien, 1906.

## Engineering and Mining Journal.

*The Mineral Industry*, 1906. Vol. xv. 8vo. New York, 1907. Price, \$5.00.

[SECRETARY'S NOTE.—I have reviewed this volume at considerable length in the *Engineering and Mining Journal* of August 31, 1907, to which members are referred for a more detailed account and estimate of it than can be given here. What I have room to say in this place hardly needs to be said at all; since the unequaled value to all students and practitioners of this annual summary, with its recent statistics and critical surveys of current technical literature, is recognized throughout the world. I can only add that the present volume is fully equal, and in some respects superior, to Vol. XIV. Mr. Ingalls and his staff are to be congratulated upon its early appearance, comprehensive contents, and intelligent editing.—R. W. R.]

WEED, W. H. *The Copper Mines of the World*. xiv, 375 p. 8vo. New York, 1907.

[SECRETARY'S NOTE.—This book, written and compiled by one who achieved recognition as one of the leading economic geologists of the United States Geological Survey, comprises two parts, the first of which, treating of The Geology of Copper, discusses the distribution of copper-deposits, their mineralogical characters, geological relations, genesis, and classification. (Chapter II., dealing with the production, market price, cost of mining, etc., is included in this part.) The second part comprises descriptions of the principal copper-mines of the world: Europe, Africa, Asia, Japan, Australasia, South America, The West Indies and Central America, Canada and Newfoundland, and, finally, the United States, occupying successive chapters. The present commercial importance of copper, and of the question of its future supply, involving the principles which may serve to guide the prospector in the search for new and productive sources, amply justifies this separate work on that subject, although neither the formation nor the exploration and exploitation of the deposits of this metal are as yet known to be governed by peculiar laws of nature or to require peculiar methods of human industry. Mr. Weed's book will be useful to those who wish to pursue this subject specially. I need hardly say that it gives evidence of the author's intelligent and conscientious ability.—R. W. R.]

## Kentucky Geological Survey.

KENTUCKY—GEOLOGICAL SURVEY. *Lead- and Zinc-Bearing Rocks of Central Kentucky*. 8vo. Louisville, 1905. (Bulletin No. 5.)

——— *Chemical Report of Coals, Clays, Mineral Waters, etc.* 8vo. Louisville, 1905. (Bulletin No. 3.)

——— *Coals of Big Sandy Valley*. 8vo. Louisville, 1907. (Bulletin No. 9.)

——— *Some Kentucky Clays*. 8vo. Louisville, 1906. (Bulletin No. 6.)

**Keystone Consolidated Publishing Co., Pittsburg, Pa.**  
*Coal Field Directory*, 1907. 448 p. 8vo. Pittsburg, 1907.

[**SECRETARY'S NOTE.**—The publishers declare that this new edition of their Directory has been thoroughly revised throughout, and that all its statements are based upon data subsequent to Feb. 1, 1907. The book comprises complete lists of the companies operating in the several States, and in Canada, including under each, as far as possible, besides the address of the company, the name and character of its mines; the particulars of its railroad connections; the names of its general manager, purchasing agent, superintendent, mine-foreman, electrician, etc.; the systems of mining and haulage employed; the equipment of the power-plant; the number of coke-ovens; the number of workmen, etc. These facts are given under geographical headings, the collieries of each State being grouped together. But there is also an alphabetical index of all the companies. The volume is copiously interleaved with advertisements, of which it contains an alphabetical index, besides a "Buyers' Business Guide." To those high-toned critics who may object to these obtrusive "business" features, two observations may be fairly addressed: first, that without the revenue derived from advertisements, nobody could afford to perform the labor of preparing and publishing the valuable information contained in the rest of the book; and, secondly, that after the lapse of a very few years, the advertisements contained in such a work will be found to be, for many purposes, the most valuable part of it, since they will constitute the highest, because the most direct and unconscious, evidence of existing practice at the date of publication. Whoever has had to deal with patents for inventions knows what such evidence is worth; and whoever despises or destroys it will either die young, or live to regret his mistake.—R. W. R.]

**Henry Louis.**

LOUIS, HENRY. *Shaft-Sinking*. p. 131-230 il. 8vo. t. p. wanting.

[**SECRETARY'S NOTE.**—This excellent treatise constitutes Section IV. of a work on "Practical Coal Mining," now in progress of publication by the Gresham Publishing Co. of London, under the editorship of Prof. W. S. Boulton, of University College, Cardiff, Wales. Not having seen other parts of the work, I cannot form any opinion as to their thoroughness and up-to-date comprehensiveness, which are, of course, the only arguments for the purchase of them by practicing colliery-engineers. But that cannot prevent me from expressing my admiration of Prof. Louis's contribution, received in separate form by the Institute Library from the author himself. In the brief compass of 100 octavo pages, with an average of one well-chosen engraving to the page, Prof. Louis has succeeded in conveying an exceedingly clear and useful summary of the present state of the art of sinking shafts. I need hardly observe that, although his theme deals specifically with colliery-shafts, his treatment of it fairly covers the shafts required for all other kinds of mining, or other subterranean excavation. The shafts of coal-mines are usually sunk through regular beds of sedimentary rock, and for purposes of mining, on a large scale, coal-beds of known dimensions, position and value. Consequently, they are not mere works of exploration or speculation; and for this reason they present the best examples of pure underground engineering, and consequently the most instructive models for mining engineers. Prof. Louis divides his work into two chapters, dealing respectively with "ordinary" and "special"

methods. Under the first head, he discusses the location of colliery-shafts; the excavation of material by pick and shovel, or by drilling and blasting; the support of the sides by temporary or permanent timbering and the permanent lining with masonry or metal (tubbing); the hoisting of excavated material during the progressive sinking; the removal of water by hoisting or pumping; and other features of the work. Under the second head, he describes the classic Kind-Chaudron method, with its modern adaptations; the methods for traversing quicksand by the use of sheet-piling or fore-piling; caisson-sinking of various types; and the Poetsch freezing-process, invented in 1883, by which he says about 65 shafts have been sunk during the last 25 years. The merits and limitations of this ingenious invention are set forth with discriminating justice, the only defect which I notice in Prof. Louis's discussion of it being his omission to state a most important assumption—namely, that of the perfectly quiescent condition of the water in the strata to be traversed by this method. If there is a current in or near the ground to be frozen as a preliminary step to excavation, the problem of the freezing is radically altered. Finally, Prof. Louis mentions briefly the new and highly interesting method of Reumaux, carried out in 1904-5 at Lens, France, which involves the solidifying of watery strata by the injection of cement. I should add that the brevity of this and other portions of his treatise is atoned for by references in footnotes, which will guide the reader to more detailed descriptions.—R. W. R.]

### **Pennsylvania State Library.**

PENNSYLVANIA—TOPOGRAPHIC AND GEOLOGIC SURVEY. *Topographic and Geologic Survey of Pennsylvania.* 308 p. 8vo. Harrisburg, 1906.

### **Dr. R. W. Raymond.**

HAMMERSLY, L. R., Publisher. *Biographical Sketches of Distinguished Officers of the Army and Navy.* 383 p. il. por. 8vo. New York, 1905.

### **T. A. Rickard.**

AUSTIN, L. S. *The Metallurgy of the Common Metals.* 407 p. 8vo. San Francisco, 1907.

[SECRETARY'S NOTE.—This treatise is published by the *Mining and Scientific Press*, of San Francisco, the new conductor of which, Mr. T. A. Rickard, seems to be continuing the policy inaugurated by Mr. Rothwell, and successfully followed by himself as Mr. Rothwell's successor in the conduct of the *Engineering and Mining Journal*—namely, the publication from time to time of books by living experts, representing actual present practice, and more convenient for the use of students and metallurgical managers than the scattered contributions contained in technical periodicals. Mr. Austin's book belongs to this class. It is too brief to be a complete, comprehensive treatise; it is most valuable in the departments of the smelting of silver-lead- and copper-ores, with which the author has had a practical experience of many years, covering the period of the great modern advance in methods and apparatus; it constitutes, in other branches, an intelligent summary, coupled with a praiseworthy and helpful attempt to reduce to general principles the multitudinous diversities of rule and habit, exhibited in the production of the different metals. All of which renders it well worthy the atten-

tion of metallurgists. That it has no alphabetical index is an awful pity, and a serious defect. The oftener we consult a volume so likely to be useful to us, the oftener we shall have cause to lament and condemn a feature which renders such consultation superfluously laborious.—R. W. R.]

WEATHERBEE, D'ARCY. *Dredging for Gold in California*.  
217 p. il. 8vo. San Francisco, Cal., 1907.

[ASSISTANT SECRETARY'S NOTE.—The most important advance in the art of extracting gold from gravels has been the development of the modern method of gold-dredging applicable to auriferous ground of suitable character outside of the channels of existing streams. Therefore, Mr. Weatherbee's book, which is specially devoted to this subject, is doubly acceptable.

The work contains a great deal of interesting and valuable information, collected by the author from active practice, and supplemented with notes and suggestions from other engineers prominent in the field of gold-dredging. Its value is greatly enhanced by nearly a hundred half-tone illustrations taken in the field, which present to the layman or student a clear idea of the construction and operation of a dredge, and to the practicing engineer special details of modern American practice. It is, indeed, refreshing to note the absence of the stereotyped illustrations found in manufacturers' catalogues, and repeatedly reproduced by writers on gold-mining and allied subjects who devote the greater part of their energy to the scissors and paste-pot. Although the field covered is limited geographically to California, much of the information given applies to other parts of the world as well. The section devoted to gold-saving appliances is worthy of special notice for its clear and concise discussion of that subject. The book, though small, is thoroughly up-to-date, and will prove valuable to practitioner or student. It is impossible, in the limited space available, to give an adequate review of the work. Perhaps the best utilization of this space is to reproduce the table of contents, and thus to show the manner in which the subject has been presented. Chapter: I., Introductory, page 9; II., Prospecting Dredging Ground, 27; III., Dredging Machines, 46; IV., Operation, 88; V., The Metallurgy of Dredging, 109; VI., Costs, 139; VII., The Horticultural Question, 164; VIII., General, 170; IX., Appendix: Contribution by J. H. Curle, 183; Gold Dredging, Editorial, 188; Sectional Dredging Machinery, Editorial, 190; Contribution by G. L. Holmes, 192; Contribution by C. W. Purington, 194; Contributions by D'Arcy Weatherbee, 200, 206; Cost of Dredging, Note, 209; Contribution by C. W. Purington, 210; Index, 215.—J. S.]

### Secretary of the American Mining Congress.

AMERICAN MINING CONGRESS. *Ninth Annual Report of the Proceedings*. 8vo. Denver, 1907.

### D. Van Nostrand Co., New York.

WALKER, S. F. *Electricity in Mining*. xx, 325 p. 8vo.  
New York, 1907. Price, \$3.50 net.

[SECRETARY'S NOTE.—Mr. Walker has had thirty years' experience in the practical application of electricity to mining work. Nobody could well have had more; for that period covers the entire history of the subject. In fact, as he remarks with justifiable pride, Mr. Walker was one of its first and most ardent



apostles, as he can fairly claim to be one of its most accomplished experts; and this volume contains the fruit of his life-work in the field he chose so early. The introductory chapters, in which he states the underlying principles and formulas, and defines the terms, of electrical science, will scarcely take the place of a more thorough introductory treatise. Such summaries seem to be regarded as necessary by the writers on technical specialties; but they are too brief to be adequate for the instruction of the wholly ignorant beginner. The real value of Mr. Walker's book is not in its explanations of theory, but in its full and critical records of practice. It is not merely a compilation from the literature of the subject. The author has his own opinion about each proposition or device, and gives his reasons for it; and they are worth considering. The best idea of the range of the book will be gained from the following list of its principal contents, after the introduction: Electric Mining Signals and Telephones; Electric Lighting for Mines; The Generation of Electricity (water-wheels, steam-engines and turbines, gas and oil-engines, dynamos, alternators, transformers, etc.); Distribution of Power by Electricity (conductors, accumulators, switchboards, fuses, circuit-breakers, etc.); The Application of Electricity to Driving Machines, etc., in Mines. A final chapter on The Practical Detection of Faults in Electrical Apparatus, is exceedingly valuable to everybody.—R. W. R.]

### Dr. Hermann Wedding.

WEDDING, DR. HERMANN. *Eisenhüttenkunde*. Vol. 4, pt. 1. 8vo. Braunschweig, 1907.

### Western Mining Directory Co., Denver, Colo.

*International Mining Manual*, 1907. Vol. 15. 4to. Denver, 1907. Price, \$10.00.

[SECRETARY'S NOTE.—This handsomely printed annual catalogue shows from year to year a decided improvement. The present edition covers the United States, Mexico and Canada, of which it gives not only the principal metal-mines and reduction-plants (including, for the Western States, Mexico and Canada, the coal-mines); but also an alphabetical register, containing more than 6,000 names of consulting, mining and metallurgical engineers, geologists, educators, and managers of mines, mills or furnaces. The publishers promise that they will extend their field, next year, to comprise also Asia, Africa, Australia, Europe and Central and South America! It is a large contract; but they have done so well thus far as to warrant confidence in their further achievements.—R. W. R.]

## MEMBERSHIP.

The following list comprises the names of those persons elected as members or associates, who accepted election during July and August, 1907:

## MEMBERS.

John A. Allen, . . . . .	Cleveland, Transvaal, So. Af.
James C. Bayles, . . . . .	New York, N. Y.
Frank H. Brown, . . . . .	Salt Lake City, Utah.
Harry L. Brown, . . . . .	Ames, Colo.
Frank M. Chambers, . . . . .	Columbia, Nev.
Floyd E. Cunningham, . . . . .	Pennington Gap, Va.
Emil E. Dieffenbach, . . . . .	Newark, N. J.
Robert I. Dunn, . . . . .	Seattle, Wash.
George M. Dyott, . . . . .	Pittsburg, Pa.
George R. D. Easley, . . . . .	Mackay, Idaho.
Adrian D. Eatherly, . . . . .	Chilton, W. Va.
Edwin E. Ellis, . . . . .	Galena, Ill.
Norman R. Fisher, . . . . .	Haileybury, Ontario, Canada.
Kenneth L. Gilson, . . . . .	Trondhjem, Norway.
James H. Gray, . . . . .	New York, N. Y.
Kiohey Hasegawa, . . . . .	Bisbee, Ariz.
Paul L. T. Heroult, . . . . .	New York, N. Y.
Preston K. Horner, . . . . .	Ely, Nev.
J. Banks Hudson, . . . . .	Gadsden, Ala.
William McM. Huff, . . . . .	Kellogg, Idaho.
James Humes, . . . . .	Basin, Mont.
John M. Humphrey, . . . . .	Centralia, Pa.
Charles H. Humphreys, . . . . .	Mt. Morgan, Queensland, Aus.
A. C. de Jongh, . . . . .	Nijmegen, Holland.
Ralph M. Kellogg, . . . . .	Searchlight, Nev.
Alfred Kimber, . . . . .	New York, N. Y.
F. Foster Kip, . . . . .	Temosachic, Chihuahua, Mex.
Julius Kruttachmitt, Jr., . . . . .	Chicago, Ill.
Carl O. Lindberg, . . . . .	Mexico City, Mex.
William J. Linn, . . . . .	Chicago, Ill.
Hans v. und z. Loewenstein, . . . . .	Essen-Ruhr, Germany.
Charles T. Malcolmson, . . . . .	Norfolk, Va.
Ronald V. A. Mills, . . . . .	San Pedro, New Mexico.
Maxwell C. Milton, . . . . .	Bisbee, Ariz.
McHenry Mosier, . . . . .	Bisbee, Ariz.
Kintaro Nagai, . . . . .	Tokio, Japan.
Keijiro Nakamura, . . . . .	Niigun, Iyo, Japan.
Louis Phillip, . . . . .	Rio de Janeiro, Brazil, So. Am.
John N. Reese, . . . . .	Harrisburg, Pa.

George E. Rose, . . . . .	Chicago, Ill.
David B. Rushmore, . . . . .	Schenectady, N. Y.
Edward F. Schaefer, . . . . .	New York, N. Y.
Frederic H. Sexton, . . . . .	Halifax, Nova Scotia.
Rudolf von Seyfried, . . . . .	Newark, N. J.
James B. Shaw, . . . . .	Mt. Morgan, Queensland, Aus.
S. F. Shaw, . . . . .	Santa Barbara, Chihuahua, Mex.
Trevor B. Simon, . . . . .	Columbus, Ohio.
Robert D. Skelley, . . . . .	Ishpeming, Mich.
H. J. Stehli, . . . . .	New York, N. Y.
Paul X. Stoffel, . . . . .	Mapimi, Durango, Mex.
William S. Sultan, . . . . .	Globe, Ariz.
Henry N. Thomson, . . . . .	Anaconda, Mont.
Paul B. Tracy, . . . . .	Bingham Canyon, Utah.
Robert Wallace, . . . . .	Eulalia, Chihuahua, Mex.
Henry L. J. Warren, . . . . .	Salt Lake City, Utah.
Clement L. Webster, . . . . .	Charles City, Iowa.
Alf. Welhaven, . . . . .	Chittababie, Korea.

#### ASSOCIATES.

William S. Bartlett, . . . . .	London, E. C., England.
John A. Leavell, . . . . .	Temple, Ariz.

#### NECROLOGY.

The deaths of the following members and associates have been reported to the Secretary's office during July and August, 1907:

Date of Election.	Name.	Date of Decease.
1896.	*Chauncey E. Butler, . . . . .	_____
1883.	*George C. Hewett, . . . . .	August 12, 1907.
1904.	*Thomas E. Johns, . . . . .	_____
1902.	**Sydney Thow, . . . . .	June 24, 1907.
1905.	††Jean A. Variclé, . . . . .	July 26, 1907.
1891.	*James W. R. Young, . . . . .	February 19, 1906.

\* Member.

\*\* Life Member.

†† Life Associate.

## CANDIDATES FOR MEMBERSHIP.

The following persons have been proposed for election as members or associates of the Institute during the period, July 1 to Aug. 31, 1907. Their names are published for the information of members and associates, from whom the Committee on Membership earnestly invites confidential communications, favorable or unfavorable, concerning these candidates. A sufficient period (varying in the discretion of the Committee, according to the residence of the candidate) will be allowed for the reception of such communications, before any action upon these names by the Committee. After the lapse of this period, the Committee will recommend action by the Council, which has the power of final election. The names of candidates were formerly published in the various circulars of the Institute, issued from time to time to the members. Hereafter, they will appear regularly in the *Bi-Monthly Bulletin*, each number of which will contain the names received since the issue of the preceding *Bulletin*.

### MEMBERS.

Charles W. Abbott, . . . . .	Pioche, Nev.
George Stitzel Backus, . . . . .	Smuggler, Colo.
Albert Babbitt Bartlett, . . . . .	Cheyenne, Wyo.
Joseph Brown, . . . . .	Kelly, N. M.
Robert Alex. Bryce, . . . . .	Cobalt, Ontario, Can.
Lloyd Thomas Buell, . . . . .	Copperhill, Tenn.
Laurence N. B. Bullock, . . . . .	Copalia, Sinaloa, Mex.
Forest Beamer Caldwell, . . . . .	Santa Lucia, Sinaloa, Mex.
John R. Chamberlin, . . . . .	New York, N. Y.
Fred C. Christy, . . . . .	Cananea, Sonora, Mex.
Edward Thomas Corkill, . . . . .	Toronto, Can.
Frederick G. Crist, . . . . .	San Dimas, Durango, Mex.
Timothy Irwin Crowley, . . . . .	Hornitos, Cal.
Bracey Curtis, . . . . .	Nogales, Ariz.
A. H. Donnewald, . . . . .	Baddeck, C. B., Nova Scotia, Can.
Francis Volney Drake, . . . . .	Bishop, Cal.
Elmer Whipple Durfee, . . . . .	Bingham Canyon, Utah.
Samuel C. Farreuf, . . . . .	Rosario, Sinaloa, Mex.
Frederick B. Flinn, . . . . .	East Orange, N. J.
James Adolphus Force, . . . . .	Tonopah, Nev.
Isaac P. Fraizer, . . . . .	Coram, Cal.
Gay Nichols Freeman, . . . . .	Thermopolis, Wyo.

Fortunato Pereira Gamba, . . . . .	Pasto, Colombia, S. America.
Herbert William Gartrell, . . . . .	Bisbee, Ariz.
John Chester Gibson, . . . . .	Pefion Blanco, Durango, Mex.
Charles Edward Gilman, . . . . .	San Francisco, Cal.
Clyde T. Griswold, . . . . .	Victoria Mines, Ontario, Can.
Joseph Harold Hedges, . . . . .	Guanacevi, Durango, Mex.
Enoch Henderson, . . . . .	Matchwood, Mich.
Herbert T. Herr, . . . . .	Duquesne, Ariz.
Hiram W. Hixon, . . . . .	Victoria Mines, Ontario, Can.
A. C. Horton, Jr., . . . . .	Grand Rapids, Mich.
Henry M. Huxley, . . . . .	Worcester, Mass.
Clements Frederick Vivian Jackson, . . . . .	Brisbane, Queensland, Australia.
Dion L. Johnson, . . . . .	Duquesne, Pa.
Bethune Glass Klugh, . . . . .	Sharpsville, Pa.
Cyril Workman Knight, . . . . .	Toronto, Can.
Frank C. Loring, . . . . .	Cobalt, Ontario, Can.
Duncan Fraser McAulay, . . . . .	Peak Hill, West Australia.
Robert S. McGarraugh, . . . . .	Penos Altos, Chihuahua, Mex.
John Walter McKim, . . . . .	Salt Lake City, Utah.
F. Oskar Martin, . . . . .	Mullan, Idaho.
John A. Mitchell, . . . . .	Haileybury, Ontario, Can.
George Edgar Montandon, . . . . .	Graneros, Chili, S. America.
William James Morrison, . . . . .	Toronto, Can.
Francisco Narvaez, . . . . .	Pachuca, Hidalgo, Mex.
Frederick Stanton Pheby, . . . . .	Ely, Nev.
Cecil Walter Pocock, . . . . .	San Pedro, N. M.
Alexander Scott Reid, . . . . .	London, England.
Robert Stewart Reid, . . . . .	La Paz, Bolivia, S. America.
Alexander J. M. Ross, . . . . .	Lead, S. Dak.
Robert Smart, . . . . .	White Horse, Yukon, Can.
Morton Stevens, . . . . .	Philadelphia, Pa.
Henry Ashe Tilghman, . . . . .	Hot Creek, Nev.
Albert Y. Waddey, . . . . .	Guayaquil, Ecuador, S. America.
Julius Herbert Warner, . . . . .	Haileybury, Ontario, Can.
Alois Weiskopf, . . . . .	Hanover-Kleefeld, Germany.
W. F. Wheeler, . . . . .	Urbana, Ill.
Philip Robert Whitman, . . . . .	Temosachic, Chihuahua, Mex.
Francis Graham Wickware, . . . . .	New York, N. Y.

# ASSOCIATES.

Glenn Armour Rickes, . . . . .	Houghton, Mich.
Alexander Herbert Smith, . . . . .	Glasgow, Scotland.

## CHANGE OF ADDRESS OF MEMBERS.

The following changes of address of members have been received at the Secretary's office during the period of July 1 to Sept. 1, 1907. This list, together with the list of changes of address published in *Bi-Monthly Bulletin*, No. 14, March, 1907, No. 15, May, 1907, and No. 16, July, 1907, supplements the annual list of members corrected to Jan. 1, 1907, and brings it up to the date of Sept. 1, 1907. The names of members who have accepted election during July and August, 1907 (new members), are printed in *italics*.

The large number of changes of address since Jan. 1, 1907, shows the importance of publishing these changes as frequently as possible, and the *Bi-Monthly Bulletin* has been selected as the means to present this information to the members of the Institute. By the simple method of cutting out these names and addresses and pasting them directly over the corresponding names in the annual list of members, the record can be kept practically up to date, and the value of the list correspondingly increased. For this purpose the changes of address have been printed only on one side of the page. The names of new members, being in *italics*, are readily distinguished from the others, and can be pasted in approximate alphabetical order on the margins of the pages.

- ADAMS, HENRY, Min. Eng., Genl. Mgr., Rush Creek Placer Mining Co., Ltd.,  
Quincey, Placer Co., Cal.
- ADAMS, RALPH E., Minas Tecolotes y Anexas.....Santa Barbara, Chih., Mexico.
- ADAMS, W. EDWARD, Min. Engr., U. S. Deputy Mineral Surveyor,  
Lewiston, Idaho.
- AHIER, PHILIPP D., Supt., Cariboo McKinney Lessees,  
Camp McKinney, B. C., Canada.
- AHLES, ROBERT L., Sweet's Steel Co.....Williamsport, Pa.
- ALEXANDER, GEORGE E., Min. and Met. Engr.....Sparta, Ore.
- \*Allen, John A., Assayer, Treasury Gold Mine, Cleveland,  
Transvaal, South Africa. '07.
- ARMSTRONG, HARLEY J.....Care Marshall Wells Hardware Co., Portland, Ore.
- ASTLEY, J. W.....Victoria, B. C., Canada.
- ATKIN, AUSTIN J. R., Golden Horseshoe Synd., Ltd.,  
Steynsdorp via Oshoek P. O., Transvaal, South Africa.



- BAILEY, EDWARD T., Asst. Mgr., African Gold Dredging & Mining  
Concessions, Ltd., Axim, Gold Coast Colony, West Africa.
- BARBER, G. M.....Chinipas, Chihuahua, Mexico.
- BARBOUR, PERCY E., Genl. Supt., Nevada Copper Mining & Smelting Co.,  
Montezuma Club, Goldfield, Nev.
- †Bartlett, William S., Secy. to Public Companies,  
138 Leadenhall St., London, E. C., England. '07.
- \*Bayles, James C., Cons. Engr.....242 W. 104th St., N. Y. '07.
- BEALE, ADDISON H.....Vandergrift, Pa.
- BEATTY, A. CHESTER.....71 Broadway, New York, N. Y.
- BELLAM, HENRY L.....Reno, Nev.
- BELLINGER, HERMANN C., Bingham Cons. Mining & Smelting Co.,  
700 McCornick Bldg., Salt Lake City, Utah.
- BENTON, C. W.....2436 Ogden St., Denver, Col.
- BLAKEMORE, GEORGE H., Great Cobar, Ltd.,  
Genl. Mgr.'s Office, Lithgow, N. S. W., Australia.
- BOSCHEN, WILLIAM C.....1 W. 89th St., New York, N. Y.
- BRADLEY, FREDERICK W.....Crocker Bldg., San Francisco, Cal.
- BRASCHI, VICTOR M., Engr. and Contractor, Calle de Cadena No. 2,  
Mexico City, Mexico.
- BROOKS, JOHN MCM., JR., Care Cia Metalurgica y Refinadora  
del Pacifico, S. A., Fundicion, Sonora, Mexico.
- \*Brown, Frank Harold, Mining, Newhouse Mines and Smelters,  
Salt Lake City, Utah. '07.
- \*Brown, Harry L., Mine Supt., Morning Star Mining Co., Ames P. O., Colo. '07.
- BURCH, ALBERT, Min. Engr.....Crocker Bldg., San Francisco, Cal.
- BURBALL, FREDERICK P., Genl. Supt., Daly-Judge Mine.....Park City, Utah.
- CARPENTER, ALVIN B., Min. Engr.....535 Rose Avenue, Hollywood, Cal.
- \*Chambers, Frank M., Supt., Columbia Sampler, Western Ore Purchasing Co.,  
Columbia, Nev. '07.
- CHURCH, JOHN L., Min. Engr.....416 Lyceum Bldg., Duluth, Minn.
- CLELAND, E. DAVENPORT, Care Secretary Chamber of Mines,  
Eagan St., Kalgoorlie, Western Australia.
- COOK, EDWARD H., Cons. Min. Engr.....P. O. Box 787, Tucson, Ariz.
- COX, THOMAS, Cerro de Pasco Mining Co., Casilla, 989, Lima, Peru, So. America.
- \*Crowell, Raymond B., Min. Engr.....Carson City, Nev. '07.
- CUMMINGS, WILLIAM N.....Care E. Randolph, Tucson, Ariz.
- \*Cunningham, Floyd E., Min. Engr.....Pennington Gap, Va. '07.
- \*Ousons, Jack, Asst. Mgr., Arminius Chemical Co., Inc.....Mineral, Va. '07.
- DAVIS, F. HARLEY, Mgr., Davis Drilling & Prospecting Co.,  
5 Watts Bldg., Birmingham, Ala.
- DEBENHAM, ARTHUR J., Asst. Engr., Pioneer Tin Mining Co.,  
Bradshaw's Creek, Tasmania.
- DEKALE, COURTENAY.....406 Wilcox Bldg., Los Angeles, Cal.
- DELANO, F. A., Prest., Wabash Railroad Co., Western Union Bldg., Chicago, Ill.
- DEMPSTER, WILLIAM.....1 Kings Park Ave., Mount Florida, Glasgow, Scotland.
- DENNY, HARRY S., 704 Salisbury House, London Wall, London, E. C., England.
- DEVEREUX, WALTER B.....15 William St., New York, N. Y.
- \*Dieffenbach, Emil E., Met.....45 Hedden Terrace, Newark, N. J. '07.
- DIGGLES, JAMES A., Broken Hill South Blocks, Ltd.,  
Broken Hill, N. S. W., Australia.
- DIGGLES, ROBERT N.....Burlingame, San Mateo Co., Cal.









- HUDSON, ALBERT H., Hotel Manitou, 123 East 3d South St., Salt Lake City, Utah  
*\*Hudson, J. Banks*, Genl. Supt.....Blast Furnaces, Gadsden, Ala. '07.  
*\*Huff, William McM.*, Assayer.....Kellogg, Idaho. '07.  
*\*Humez, James*, Mine Supt.....Basin, Mont. '07.  
*\*Humphrey, John M.*, Div. Supt., Lehigh Valley Coal Co.,  
 Centralia, Columbia Co., Pa. '07.  
*\*Humphreys, Charles H.*, Met.....Mount Morgan, Queensland, Australia. '07.  
 HUTCHINSON, JOSEPH H....110 W. Ramsey St., or P. O. Box 578, Goldfield, Nev.  
 HYDER, CHARLES A., Care Hyder & Hyder, Mining Engineers,  
 Moctezuma, Sonora, Mexico.  
 JARVIS, ROYAL P., Prof. of Mining.....800 N. 3d Ave., Knoxville, Tenn.  
 JOHNSTON, J. HOWARD, Care Morgan, Harjes & Co.,  
 31 Boulevard Haussmann, Paris, France.  
 JONES, CHARLES C.....301 Henne Bldg., Los Angeles, Cal.  
*\*de Jongh, A. C.*, Min. Engr. for the Dutch Colonial Government,  
 39 Rosendaelstrasse, Nymegen, Holland. '07.  
 KAEDING, HENRY B.....1421 Winfield St., Los Angeles, Cal.  
 KEITH, NATHANIEL S.....350 Bullitt Bldg., Philadelphia, Pa.  
 KELLER, ARTHUR H., Min Engr.....Louiser Str. 24 II, Munich, Germany.  
 KELLER, F. H.....Omak, Wash.  
*\*Kellogg, Ralph M.*, Mine Supt.....Searchlight, Nev. '07.  
 KEYES, CHARLES R.....944 Fifth St., Des Moines, Ia.  
 KIDDIE, THOMAS, Mgr., The Alaska Smelting & Refining Co.,  
 Hadley, Prince of Wales Island, Southeast Alaska.  
 KIDWELL, EDGAR, Genl. Mgr., Hammel Oil Burner Co.,  
 3002 Hobart Blvd., Los Angeles, Cal.  
*\*Kimber, Alfred*, Civ. and Min. Engr., Care Ladenburg, Thalmann & Co.,  
 25 Broad St., New York, N. Y. '07.  
*\*Kip, F. Foster*, Min. Engr., Greene Gold-Silver Co.,  
 Temosachic, Chihuahua, Mexico. '07.  
 KLEPETKO, FRANK.....90 West St., New York, N. Y.  
 KLINE, RALPH C.....Care Fianza Mining Co., Guanacevi, Durango, Mexico.  
*\*Kruttschnitt, Julius, Jr.*, Min. Engr.....49 Bellevue Place, Chicago, Ill. '07.  
 LACK, FRANK S.....518 Stimson Bldg., Los Angeles, Cal.  
 LAMB, R. B.....Kendall, Mont.  
 LANG, J. G.....Beechwood, Crieff, N. B., Scotland.  
 LAWN, JAMES G., Head of Mining Dept., Camborne School of Mines,  
 Camborne, England.  
 LAWRENCE, CHARLES E.....Iron Mountain, Mich.  
 LAWRIE, HAROLD N.....White Salmon, Wash.  
 †*Leavell, John A.*, Senior Student, Care Charles M. Campbell,  
 Temple, Texas. '07.  
 LEE, RICHARD H., Supt. of Blast Furnaces, The Pennsylvania Steel Co.,  
 Lebanon, Pa.  
 LEGGETT, THOMAS H.....Care Smith & Perkins, 15 Broad St., New York, N. Y.  
 LEVENSALE, LEWIS A.....Valdez, Alaska.  
 LEWIS, J. VOLNEY, Care Washington & Lewis, Cons. Geologists to Min. Engrs.  
 95 Liberty St., New York, N. Y.  
*\*Lindberg, Carl O.*, Min. Engr., Care Carpenter & Brennon,  
 519 La Mutua, Mexico City, Mexico. '07.  
*\*Linn, William J.*, Mining.....2629 Michigan Ave., Chicago, Ill. '07.  
 LIVINGSTONE, CHARLES H.....Selby Smelting & Lead Co., Selby, Cal.



- LONGACRE, ORLEANS.....Prescott, Yavapai Co., Ariz.  
 \*Lowenstein, Hans von und zu, Mgr. of the Dortmund Mining Association,  
 2 Friedrichstrasse, Essen-Ruhr, Germany. '07.  
 LYDECKER, IRVING S.....R. F. D. No. 5, New Brunswick, N. J.  
 MCCAUSTLAND, ELMER J., Prof. of Mining Engineering,  
 University of Alabama, Tuscaloosa, Ala.  
 MCKAY, HOOD, Supt., Eastern Division,  
 Lehigh Coal & Navigation Co., Lansford, Pa.  
 MACDONALD, JESSE J.....Tucson, Ariz.  
 MACKAY, HENRY S.....408 Merchants Exchange, San Francisco, Cal.  
 MACPHERBAN, R. S.,.....Care J. I. Case Threshing Machine Co., Racine, Wis.  
 \*Malcolmson, Charles T., Engr. in charge Briquetting Div., Government  
 Coal Testing Plant, Jamestown Exposition, Norfolk, Va. '07.  
 MAYNARD, REA E.....Room 1409, Chronicle Bldg., San Francisco, Cal.  
 METCALF, WILLIAM.....5821 Wilkins Ave., Pittsburg, Pa.  
 \*Mills, Ronald V. A., Min. Engr.....San Pedro, New Mexico. '07.  
 \*Milton, Maxwell C., Min. Engr.....Bisbee, Ariz. '07.  
 MITINSKI, ALEXANDER N.....47 Kiotschuaya, St. Petersburg, Russia.  
 MONELL, JOSEPH T., Cons. Engr.....3454 Halliday Ave., St. Louis, Mo.  
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## Blow-Holes in Steel Ingots.

BY E. VON MALTITZ, METALLURGICAL ENGINEER, SOUTH CHICAGO, ILL.

(Toronto Meeting, July, 1907.)

IN his highly interesting paper on "Piping and Segregation in Steel Ingots,"<sup>1</sup> Prof. Howe emphasizes the effect of successive phases of internal pressure in the ingot in the evolution of gas, and the consequent formation of blow-holes. From his statements in other places, it may be inferred that he does not here intend to ignore the other variable factor, temperature, but rather to discuss this one more particularly. At all events, it is my purpose not to engage in controversy with Prof. Howe, but rather to contribute, towards the complete elucidation of this important subject which we all desire, my own views and experience. If, in doing so, I specially emphasize other factors than pressure, I need not be understood as denying what I do not think it necessary to discuss fully. Nor, in presenting my own original conclusions, need I be understood as claiming to be the first who ever reached or announced them. Many things are asserted or suggested upon inconclusive evidence; and to confirm such tentative propositions may be as valuable a service as to overthrow them.

In the following passage, Prof. Howe adduces analogies, based upon the behavior of charcoal and of water, respectively, which seem to me questionable:

"In general, the solvent power falls as the pressure falls; and in general it rises as the temperature falls. Thus, to heat a solid, for instance charcoal, may expel part of its dissolved gas; and a tumbler of water drawn cold from the faucet gradually evolves gas, as it stands and warms up on the sideboard." (p. 238.)

Charcoal is a solid body, which has the property not only of absorbing gases in large quantities, but also of expelling the thus absorbed gases upon heating. A comparison between charcoal and iron as to the absorption of gases is scientifically not possible; the gas-content of charcoal is partly due to the

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<sup>1</sup> *Bi-Monthly Bulletin*, No. 14, March, 1907, pp. 169-274.

incomplete decomposition of the wood, partly to the extremely great porosity of the charcoal, which gives a very large surface. This surface attracts certain gases, and favors formation of new gases in the cold by the contact with the oxygen and moisture of the atmosphere.<sup>3</sup> To arrive at a right comparison we must take solid iron and see if this body is able to take up gases and to set them free again with changing temperature.

#### I. DOES SOLID IRON ABSORB AND RELEASE GASES WITH CHANGING TEMPERATURE ?

Graham (1866)<sup>4</sup> found that iron together with other metals has the property of absorbing hydrogen; Parry, Troost and Hautefeuille verified this discovery. The latter experimenters heated pieces of solid iron, of 500 g. each, up to 800° C. in an atmosphere of hydrogen and of carbon monoxide, respectively. They found that the iron at this temperature was able to absorb three times as much hydrogen as carbon monoxide; these gases were again given off *in vacuo*. This points to the fact that solid iron is able to absorb gases upon heating. A. Ledebur<sup>5</sup> found that steel became very brittle, when pickled in dilute sulphuric acid or hydrochloric acid. An analysis of such steel showed that it had taken up 0.002 per cent. of hydrogen. Johnson,<sup>6</sup> Hughes,<sup>6</sup> and Baedeker,<sup>7</sup> experimenting along the same line, came to the same conclusions. H. von Jüptner<sup>8</sup> found that hydrogen is able to diffuse through sheet iron, when corroded by dilute sulphuric acid or hydrochloric acid, and produces large bubbles in defective places, in which bubbles the gas is contained under considerable pressure. Roberts-Austen<sup>9</sup> found that pure iron, obtained by electrolytic precipitation from a chemically pure solution of ferric chloride, gave up large quantities of hydrogen, when heated in water up to 70° C., and that it continued to do so,

<sup>3</sup> Poggendorf's *Annalen*, vol. cix., p. 353 (1860).

<sup>4</sup> Graham, *Collected Works*, p. 279.

<sup>5</sup> *Stahl und Eisen*, vol. vii., p. 681 (1887); vol. ix., p. 745 (1889).

<sup>6</sup> *Proceedings of the Royal Society*, vol. xxiii., p. 168 (1875).

<sup>7</sup> *Journal of the Society of Telegraph Engineers*, vol. ix., p. 163 (1880).

<sup>8</sup> *Zeitschrift des Vereines deutscher Ingenieure*, vol. xxxii., p. 186 (1888).

<sup>9</sup> H. v. Jüptner, *Siderology*, vol. i., p. 285.

<sup>9</sup> *Proceedings of the Institution of Mechanical Engineers*, 1891, p. 543. Report to the Alloys Research Committee.

when heated *in vacuo* in a porcelain tube, up to  $1,800^{\circ}\text{C}.$ , at which temperature the liberation of hydrogen became a minimum. Repeated heating of the same iron up to  $1,800^{\circ}\text{C}.$  deprived it of all its hydrogen; it could, however, be loaded again with hydrogen, when the iron was hung as the negative electrode in diluted acid. All these investigations point out that iron is able to absorb hydrogen at low temperature, and that its maximum solvent power for this gas must be close to  $70^{\circ}\text{C}.$

E. Heyn<sup>10</sup> heated soft steel in an atmosphere of hydrogen up to  $1,000^{\circ}\text{C}.$  In order to keep the hydrogen in the steel he quenched the test in cold water, and found that it exhibited great brittleness, decidedly more than similar steel when heated up to  $1,000^{\circ}\text{C}.$  in air and then quenched in cold water. Analyzing the steel, he found that it contained 0.00019 per cent. hydrogen. After heating the steel in hydrogen up to  $1,000^{\circ}\text{C}.$  he cooled it down slowly in air. When this cooling was continued until the temperature of the steel was below  $730^{\circ}\text{C}.$  any noticeable effect on the steel by this treatment could not be detected.

From this it follows, that iron (and steel) must absorb hydrogen at temperatures between  $730^{\circ}$  and  $1,000^{\circ}\text{C}.$ , and further, that iron (and steel) must experience a decrease in its solvent power for hydrogen, when cooling below  $730^{\circ}\text{C}.$ , or, in other words, the metal must liberate hydrogen when cooling below  $730^{\circ}\text{C}.$

From these investigations we arrive at the following conclusions:

(a) Solid iron (and steel) has two maxima in its solvent power for hydrogen; one at about  $70^{\circ}\text{C}.$  and another between  $730^{\circ}$  and  $1,000^{\circ}\text{C}.$

(b) Solid iron (and steel) gives off hydrogen, absorbed at a temperature above  $730^{\circ}\text{C}.$ , when cooling below this temperature.

(c) Solid iron (and steel) gives off hydrogen and other gases upon heating.

Water, which furnishes the second analogy, is a liquid body, and should therefore be compared with liquid bodies only—in this case with molten steel. We know that water sets free

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<sup>10</sup> *Stahl und Eisen*, vol. xx., p. 36 (1900).

occluded gases upon heating, and that continued boiling will drive out all the air contained in it. On the other hand, however, we know, also, that water sets free occluded gases upon freezing, and that these gases, when they cannot escape, form blow-holes in the block of ice. Water, made gas-free by continued boiling, will freeze without blow-holes; but if we blow air through such gas-free water, as it approaches the freezing-point, the ice, when formed, will have blow-holes.

The liquid water has therefore two points of minimum solvent power for gases, the freezing- and the boiling-point. Between these two minima, there must naturally lie a maximum of this solvent power—at what temperature I am unable to say. But it suffices for our purpose that water, when fluid, is able to absorb gases.

## II. IS MOLTEN STEEL ABLE TO ABSORB GASES?

We know that steel, when freezing, evolves gases and forms blow-holes, exactly like freezing water. And, like water, the steel must have had, at some point during the time it was in the molten state, the capacity to absorb gases in such amount that, upon freezing, it is unable to keep them in bond, and therefore sets them free. In other words, solid steel cannot contain as much occluded gas as molten steel. When we melt this solid steel in the open-hearth furnace, it must at some temperature acquire a decidedly greater solvent power for gases; otherwise, no blow-holes would be formed.

If water is able to absorb gases at a certain temperature, which is above its freezing-point, why may not steel do the same with regard to hydrogen and nitrogen?

Are we not forced to accept a third maximum in the solvent power of steel for gases, which lies away above  $1,000^{\circ}\text{C.}$ , in fact, at a considerable distance from the melting-point?

Heating to still higher temperatures must decrease the solvent power for gases rapidly again, for we know that steel, poured extremely hot (and without overoxidation), will give perfectly solid ingots and castings.

To compare water once more with molten steel, we find that a solid block of ice or steel, containing a minimum of gases in the form of blow-holes, will, as it is melting and being subjected to a continuous rising temperature, approach a maximum in its

solvent power for gases, and after having passed this maximum will, upon further heating, experience a rapid decrease in its solvent power.

If we accept the theory that increasing temperature lowers the solvent power of molten steel for gases, why is it that the steel does not lose all its gases in the furnace, where it is at its highest temperature? And if, with decreasing pressure, the solvent power also falls, why are not the gases driven out in the furnace, where there is a slight pressure at the incoming side for gas and air, but a relative depression at the outgoing side, due to the draft? Each reversal of the gas and air puts more than 50 per cent. of the bath under lower pressure, and its solvent power should fall with that decrease. The opportunity to give off gases would certainly be splendid here, on account of both higher temperature and lower pressure. But does the steel shew such action? Why does it wait with the liberation of the occluded gases until it is poured into the molds? Are we not justified in looking for other reasons for the formation of blow-holes in steel ingots than those given by Prof. Howe? To arrive at the right conclusions, it is necessary to first study the nature of the gases, which are found in blow-holes, and then to ask if these gases, which are found in these cavities, are alone responsible for their formation—in other words: if the blow-holes are formed solely by those gases found inclosed in them, without the interference of a third gas.

### III. WHAT IS THE NATURE OF THE GASES FOUND IN BLOW-HOLES?

The classical investigations of Dr. F. C. Müller, Messrs. Stead and Richards, and others, on the gases contained in blow-holes of steel ingots, have shown that these gases consist chiefly of hydrogen and nitrogen. A little carbon monoxide was found in a few instances, but always in too small a percentage to make it one of the chief constituents.

For illustration I give a few analyses of blow-hole gases:



TABLE I.—*Analyses of Blow-Hole Gases.* Taken from *Stahl und Eisen* for 1882 and 1883.

No.	Volume of Gases.	Composition of Collected Gases.			Authority.
	Per Cent.	H <sub>2</sub> . Per Cent.	N <sub>2</sub> . Per Cent.	CO. Per Cent.	
1	16.5	68.8	30.5	0.0	Dr. F. C. Müller.
2	51.0	78.1	20.7	0.9	Dr. F. C. Müller.
3	17.0	92.4	5.9	1.4	Dr. F. C. Müller.
4	36.0	85.4	14.3	0.6	Dr. F. C. Müller.
5	20.0	64.5	35.4	0.0	Dr. F. C. Müller.
6	22.0	86.4	12.7	0.4	Dr. F. C. Müller.
7	6.0	54.7	45.3	0.0	Dr. F. C. Müller.
8	48.0	90.0	9.7	0.0	Dr. F. C. Müller.
9	45.0	77.0	23.0	0.0	Dr. F. C. Müller.
10	29.0	76.7	23.3	0.0	Dr. F. C. Müller.
11	21.0	81.9	18.1	0.0	Dr. F. C. Müller.
12	25.0	67.0	30.8	2.2	Dr. F. C. Müller.
13	6.00	88.8	10.5	0.7	Dr. F. C. Müller.
14	44.0	80.0	17.9	1.3	Dr. F. C. Müller.
15	21.0	67.1	33.3	1.6	Stead and Richards.
16	1100.0	88.7	10.3	0.0	Stead and Richards.

1. Soft Bessemer steel with few blow-holes; 2. Rail steel, many blow-holes; 3. Rail steel, no blow-holes; 4. Soft Bessemer steel, many blow-holes; 5. The same, few blow-holes; 6. The same, few blow-holes; 7. The same, very few blow-holes; 8. Bessemer rail-steel; 9. The same; 10. The same; 11. Bessemer spring steel, few blow-holes; 12. Open-hearth steel, before addition of spiegeleisen; 13. Bessemer steel, before adding spiegeleisen; 14. The same; 15. Dense steel, drilled with sharp drill; 16. The same, drilled with blunt drill.

These analyses show that liberated hydrogen and nitrogen, especially hydrogen, evolved by the solidifying steel, accumulate in larger or smaller bubbles, and form the blow-holes.

It may seem strange, on first thought, that molten steel should be able to absorb so much hydrogen, since this gas cannot be present in large quantities under ordinary conditions in the atmosphere of our steel-furnaces. We know, however, that the tetravalent metals of Mendelejeff's group VIII.—viz., iron, nickel, cobalt, ruthenium, rhodium, palladium, osmium, iridium and platinum—have a characteristic high affinity for hydrogen, which will naturally be augmented when the gas is *in statu nascendi*, in which state it will combine much more readily with the metal. In our Bessemer and open-hearth proc-

esses we decompose the moisture, brought in by the air and gas respectively, so that a considerable amount of nascent hydrogen is present during the process of manufacturing steel.

#### IV. IN WHAT CONDITION ARE HYDROGEN AND NITROGEN PRESENT IN STEEL?

Many facts tend to show that we have in hydrogen not a metalloid, but the vapor of a metal which volatilizes very easily at extremely low temperature.

The high thermal conductivity of hydrogen resembles that of metals; the hydrogen is easily replaced in its combinations with metalloids partly or completely by metals; thus,  $\text{HCl} + \text{Na} = \text{NaCl} + \text{H}$ . Graham took hydrogen, therefore, as the vapor of a metal, which he called hydrogenium.<sup>11</sup>

Iron, like platinum, palladium, cobalt and nickel, readily absorbs hydrogen in volumes many times larger than its own, especially when hydrogen, as we have seen by electrolyzing a solution of ferric chloride, is present *in statu nascendi*. This iron, obtained by electrolytic precipitation, is extremely brittle and very hard. Were we to assume only a mechanical absorption of the gas by the iron, a decrease in the hardness of the metal should be expected. When we regard the hydrogen alloyed with the iron, however, the increase in hardness is quite natural, since all true alloys generally exhibit a greater hardness than the single constituent metals. If the hydrogen is alloyed with the iron, then it must be subjected to segregation, just as other alloys are. In what form the hydrogen is present in the iron is yet unknown; so much, however, seems to be sure, that that part of the hydrogen, present in the iron, which

<sup>11</sup> The phenomena of gas-absorption which some metals show, though destitute of visible pores, is probably connected with their capacity to absorb gases either on the surface or in their masses. Graham found that platinum occluded four times, and iron 0.44 times, its volume of hydrogen. This property is most remarkable in palladium, which absorbs hydrogen not only in cooling after being heated, but also in the cold. Palladium, used as electrode in the decomposition of water, will absorb 980 times its volume of hydrogen. This gas is again driven out on being heated. By the occlusion of hydrogen the volume of palladium is increased by 0.09827 of its original amount, from which it follows, that the hydrogen which under ordinary circumstances has a density of 0.000089546 that of water, has here a density nearly 9,868 times as great, or about 0.88 that of water. Hence, the hydrogen must be in the liquid or even solid (metallic) state. It probably forms thus an alloy with palladium like a true metal.—Ganot, *Éléments de Physique*.

exerts such a great influence on the physical properties of the metal, will not consist of merely mechanically occluded gas, but must be alloyed with the metal.

The investigations in regard to nitrogen in iron are very scant so far. Older investigations by Fremy, Rinmann and Allen show that steel contains not more than 0.008 per cent. of nitrogen when manufactured from the liquid state and allowed no chance by further working to take up nitrogen. H. Braune has lately proved that solid steel, which is able to take up nitrogen, when heated up to from 600° to 800° C. in dry ammonia gas, is remarkably influenced in regard to its physical properties by the nitrogen thus absorbed. Nitrogen, like hydrogen, must therefore have the capacity to combine with iron.

Whether these two gases, when taken up by the molten steel, enter completely into combination with the metal or are only partly mechanically absorbed by the steel, cannot be decided, since we are unable to analyze molten steel.

#### V. ARE HYDROGEN AND NITROGEN ALONE RESPONSIBLE FOR THE FORMATION OF BLOW-HOLES ?

The analyses of the blow-hole gases show that practically only hydrogen and nitrogen are present, and we are, therefore, apparently justified in concluding that blow-holes are formed only because these two gases were absorbed by the molten steel in quantities too large to be kept in bond completely by the solidifying metal. The gases evolved by the slowly freezing steel should, therefore, be hydrogen and nitrogen only. But in case we find some other gas evolved from the ingot in appreciable quantity besides these, we are warranted in inquiring whether this third gas has not more to do with the formation of blow-holes than the analyses of the blow-hole gases would lead us to believe.

Dr. F. C. Müller,<sup>12</sup> by analyzing the gases evolved from the slowly solidifying ingot, obtained the results shown in Table II.

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<sup>12</sup> *Stahl und Eisen*, vol. iii., p. 448 (1883).

TABLE II.—*Analysis of Gases from Cooling Ingots,*  
by Dr. F. C. Müller.

No.	CO. Per Cent.	H <sub>2</sub> . Per Cent.	N <sub>2</sub> . Per Cent.	CO <sub>2</sub> . Per Cent.	Remarks.	
1	37.3	47.3	7.9	7.5	Bessemer rail steel.	Finished steel, after addition of deoxidizing material.
2	34.0	49.5	8.6	7.9	Bessemer spring steel.	
3	43.2	19.7	36.7	0.4	Bessemer spring steel.	
4	45.9	41.4	9.9	2.8	Bessemer spring steel.	
5	38.7	51.3	7.2	2.8	Bessemer rail steel.	
6	48.2	44.5	2.5	4.8	Bessemer spring steel.	
7	38.4	51.0	2.2	8.4	Bessemer rail steel.	
8	31.5	39.2	21.6	7.7	Bessemer rail steel.	
9	68.0	16.2	11.0	4.8	Thomas rail steel.	Before addition of deoxidizer.
10	56.5	33.0	8.6	1.9	Thomas rail steel.	
11	18.6	54.2	24.9	2.3	Bessemer blown metal.	
12	18.1	52.9	26.8	2.2	Bessemer blown metal.	

We see that carbon monoxide is present in very much larger percentage in the gases evolved by the solidifying steel than in the blow-holes in the solid ingot. During some time, at least, carbon monoxide must, therefore, have something to do with the liberation of the gases occluded in the steel. What rôle it plays we cannot tell yet; but that it is concerned in the liberation of the gases is obvious. Another observation from our daily practice makes it still more likely that we have in the carbon monoxide an agent more or less directly responsible for the evolution of the occluded gases, and consequently for the formation of blow-holes. When we blow a Bessemer heat, and stop the blow just at the proper time, the steel will pour quietly after we have added the deoxidizer, and will give ingots free from blow-holes. But when we blow another heat, being very careful to have practically the same temperature as with the first, but continue the blowing for a short overtime (about 30 to 60 seconds); in other words, when we overblow the heat, the steel will pour decidedly wilder after the addition of the deoxidizer; it will rise in the molds and will give ingots with more or less broad rings of blow-holes.

Have the 30 to 60 sec. of longer blowing with the second heat overloaded the steel with hydrogen and nitrogen to such an extent as to account for the formation of the blow-holes? Is it possible that this short overblow is so much more powerful to saturate the steel with hydrogen and nitrogen than the much longer period preceding the overblow, during which the

temperature of the bath was practically at the very same height? Or may it not be due to the fact, that during this very short overblow we form a metallic oxide in the bath, which was less liable to be stable as long as the more easily oxidizable impurities were present in still appreciable amount? And could not this oxide, reacting with the carbon brought in by the deoxidizer, give rise to a considerable carbon monoxide formation, which latter gas then had a decided influence upon the liberation of hydrogen and nitrogen in the steel?

#### V. SOURCE OF THE CARBON MONOXIDE GAS.

In the manufacture of Bessemer or open-hearth steel, we take advantage of the great affinity for oxygen of the impurities contained in the iron. In the converter, we oxidize them by blowing atmospheric air through the molten metal, while in the open hearth we derive the necessary oxygen from the air and from iron oxides (iron-ore).

This oxidation calls for large quantities of oxygen; we always add a surplus of this element to our bath, or else the required reactions would not be completed in so short a time as is the case.

A part of this supplied oxygen will, therefore, stay combined with iron, which, as we know, has a great affinity for oxygen itself. In the presence of such a large surplus of metallic iron as we have in these steel processes, ferrous oxide, the most stable of the iron oxides, will be formed.

A. Ledebur found as much as 1.80 per cent. of ferrous oxide in low-carbon steel. This he found in solid steel; how much molten steel is able to contain it is impossible to say. It must be more than in solid steel, for otherwise it would be impossible for low-carbon steel (see Table II., analyses Nos. 11 and 12) to give off such large quantities of carbon monoxide.

The solvent power of steel for ferrous oxide increases with increase in purity. As long as the metal is still high in impurities, the ferrous oxide will become reduced by the more easily oxidizable elements, silicon, manganese, phosphorus and carbon. This reduction of ferrous oxide will be aided by the lower temperature, which naturally prevails in such a bath. As the temperature rises, however, the solvent power of steel for ferrous oxide increases.

We know that it is much harder to eliminate phosphorus in the open-hearth furnace at high than at low temperature, although the oxygen at hand to combine with phosphorus is by no means smaller in the former case than in the latter. But the fact that under such circumstances, even carbon, which may often be present in appreciable percentage, does not readily reduce the ferrous oxide, is somewhat bewildering, since we know that the affinity of carbon for oxygen increases with rising temperature. We cannot manufacture very low carbon steel in the open-hearth furnace or converter, without greatly overoxidizing the metal—that is, increasing the amount of ferrous oxide in it; and we are forced to conclude that at high temperature the affinity of iron for oxygen must be greater than that of carbon for oxygen. Whether in this case the iron combines with oxygen to form ferrous oxide or, perhaps, to form a still lower oxide ( $F_2O$ ), it is yet impossible to decide.

Our daily practice teaches the same law. If, from a heat high in carbon, but low in temperature, we pour a small sample with a spoon into a test-mold, the steel will solidify quietly in the mold. It will not sputter, and will not show any blow-holes when broken in two. But when we take a similar test from a heat of practically the same carbon-content, and much higher temperature, the steel will be “wild,” will sputter and rise considerably; and when broken the ingot will show many blow-holes. What is the reason for this wide difference of behavior? In the first case, although ferrous oxide was certainly formed continuously in the bath, the metal refused to dissolve it, and the carbon, having a greater affinity for oxygen than iron, immediately reduced it. Hence, the metal poured into the test-mold did not contain ferrous oxide, and, the formation of carbon monoxide in the solidifying steel being consequently impossible, the steel solidified quietly without forming blow-holes. In the second case, however, the much higher temperature of the bath increased the solvent power of the steel for ferrous oxide, while, on the other hand, the affinity of carbon for oxygen was becoming less than that of iron for oxygen. Hence, the metal poured into the test-mold contained, in the presence of carbon, an appreciable amount of ferrous oxide. The rapidly sinking temperature of the steel, approaching its freezing-point, lowered simultaneously the solvent

power of the steel for ferrous oxide and raised the affinity of the carbon for oxygen, so that a large amount of carbon monoxide was set free, which liberated hydrogen and nitrogen from the metal, and which were entangled in the metal as it passed through the pasty condition; and thus the blow-holes were formed.

In a low-carbon heat the conditions for the solution of ferrous oxide are much more favorable; since both high temperature and the higher degree of purity tend to increase the solvent power of the bath in that respect.

But what happens when we cool down such a heat artificially in the furnace? Prof. Howe says:<sup>13</sup>

"Certain metallurgists . . . point to their observation [in order to prove their statement, that the solubility of gases in molten steel decreases as the temperature falls towards the freezing-point], that when in the open-hearth furnace the charge has ceased to boil, boiling may be induced by shutting off the supply of gas altogether, which no doubt lowers the temperature."

I must confess here, that I have endeavored many times, without success, to verify this statement. I have taken heats with carbon close to 0.40 per cent., and with carbon close to 0.15 per cent., which had ceased to boil, and shut off the gas for 10, 15, 20 minutes and more, but never could detect a renewed boiling in the bath. All that I could observe was, that the slag cooled off rapidly on the surface, and therefore quickly became foamy under the bloating influence of the escaping gases (mostly carbon monoxide), which had been discharged quietly through the slag as long as the gas-flame kept it fluid and therefore easy to be penetrated. Moreover, I cannot believe that any considerable amount of cooling can take place in the bath lying, as it does, on the extremely hot hearth of the furnace, and protected by a more or less deep layer of slag. What had been believed to be a renewal of the boiling was nothing more than a change in the physical condition of the slag surface.

To cool a heat in the open-hearth furnace artificially, we may throw in pieces, not of pig-iron, which, for obvious reasons, will induce a boiling, but of steel scrap, which, in melting, cools the surrounding steel, and causes a violent local boiling.

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<sup>13</sup> In his paper, already cited, p. 238, footnote.

Or, still better, we may stir the bath with a steel bar. A high wave or crest will form immediately over the bar. The slag, unable to release readily the much larger quantity of gas, will foam up, sometimes so much as to run out of the furnace-doors. That the gas thus escaping is chiefly carbon monoxide, from the reduction of ferrous oxide by carbon, is proved by the fact that the stirring, as soon as a strong liberation of gas takes place, lowers the carbon-content in the bath considerably. This phenomenon, however, might conceivably be due to the fact, that in a steel bath, ferrous oxide and especially carbon, when present in small quantities only, will not react very readily upon each other. Both may possibly be in a state of inertia, which may be overcome by stirring or throwing in cold scrap. But opposed to this supposition, it may be stated that the liberation of gas ceases practically at once, when the steel scrap has melted, or the stirring is discontinued.

Moreover, the evolution of gas can be seen only at that locality where the scrap or the bar is at the very moment, and stops at once as soon as the scrap or the bar is moved away to some other part of the bath. The wave is always directly over the bar; if we move the bar quickly, the wave quite naturally lags behind somewhat, but still follows the bar, and subsides rapidly when the bar is removed. Were it only a state of inertia that had to be overcome, why should the reaction not continue and spread over all the bath after we had overcome the inertia in one part of the bath? We are apparently justified in concluding that the cold scrap or the stirring-rod effected a drop in the temperature of the steel in its immediate neighborhood only, and that this drop in temperature enabled the carbon to reduce the ferrous oxide, for which the solvent power of the steel was lessened simultaneously. To sum up:

(d) Although we find practically only hydrogen and nitrogen inclosed in blow-holes, these two gases are not alone responsible for the formation of the blow-holes.

(e) An important factor in the formation of blow-holes is carbon monoxide, which is present in large quantities in the gases evolved from the solidifying steel.

(f) The source of this carbon monoxide is the ferrous oxide, dissolved by the steel during the process of steel-making.



(g) Steel has a solvent power for ferrous oxide, which increases with rising temperature.

(h) Steel has a solvent power for ferrous oxide, which increases with increasing degree of purity.

(i) The affinity of iron for oxygen at higher temperature increases with rising temperature more rapidly than that of carbon for oxygen.

## VII. THE FORMATION OF THE BLOW-HOLES.

Let us consider a metal which is very liable to form blow-holes, a metal, therefore, which not only contains much hydrogen and nitrogen, but also ferrous oxide—in other words, an overblown or over-ored metal. When this metal is tapped into the ladle we observe, on adding the deoxidizing or recarbonizing materials, a strong reaction. These additions are always, even when they consist of molten spiegel or ferromanganese, decidedly colder than the molten steel. A sharp drop in temperature must take place, and ferrous oxide, reduced by carbon, forms carbon monoxide, which is not absorbed by the steel, but leaves the metal immediately on its formation. Rushing out of the liquid metal, this gas will act on that hydrogen and nitrogen, which is present in the molten steel as mechanically absorbed gas, just like air or some other gas will act on carbon dioxide, when blown through mineral water in a tumbler. Here a physical law comes into effect—viz., that when one gas is set free in a solution containing several gases, this liberated gas will set free also the other gases. Besides carbon monoxide we find, therefore, also hydrogen and nitrogen leaving the steel. J. E. Stead, analyzing the gases accumulated under a slag cover in a ladle filled with steel, found: CO, 47.3;  $H_2$ , 18.6;  $N_2$ , 31.4;  $CO_2$ , 2.5 per cent.

Closely watching the ladle which now contains all the steel, under a more or less heavy cover of slag, we see that the evolution of gases subsides more and more, and that the slag on top begins to chill rapidly, with the exception of a small ring close to the ladle-lining. Here the evolution of gases continues, and, bringing constantly fresh, hot slag to the surface, keeps the slag liquid and in constant motion. Steam, coming from a still moist ladle-lining, cannot be the cause of it, since the ladle was not only perfectly dry, but also heated

up to redness before the heat was tapped into it. The steel nearest the lining cools down somewhat, effecting the formation of carbon monoxide, hence an evolution of occluded gases from this locality. The cooling-effect of the ladle-lining is not great, but it lasts for a long time.

When we pour this metal into the molds we can often see very clearly that, after the mold is filled, the steel stays perfectly quiet in the mold for some time, and then begins to evolve gases and to rise quite suddenly. This phenomenon may be seen more readily in molds of smaller diameter than in larger ones.

What has happened in the meantime in the ingot? As soon as the steel enters the mold it experiences a sharp drop in temperature, where it comes in contact with the comparatively cold walls. Here it solidifies immediately, forming a shell, which incloses the liquid steel. This first shell contracts and draws away from the mold, leaving between ingot and mold a small space. This will certainly retard the freezing of the still liquid steel, which will now begin to solidify in layers, concentric with this shell and in perfect union with it. From the freezing of water and alloys we know that in the endeavor to crystallize out in pure iron crystals the steel will expel the impurities, which, having a lower melting-point than the purer metal, will travel towards the still fluid center of the ingot. We find, therefore, that the layers first solidified contain less impurities than the average of the original steel mass; and thus we have a purer, already solidified shell on the outside, and a liquid central part, where the impurities are still present in original amount, while between these two portions is a layer, which contains not alone the original amount of impurities, but also those rejected by the solidifying outer layer. This intermediate layer, which is still liquid, has not only taken up the carbon, manganese, phosphorus, sulphur, etc., expelled by the freezing outer layer, but also the hydrogen, nitrogen and the ferrous oxide, which were driven out of the solidifying crust.

These impurities take time to migrate through the fluid steel, and there will consequently be a gradually rising wave of impurities, traveling towards the center of the steel ingot—and also, on account of their lighter specific weight, upwards

in the ingot—leaving behind it metal which is purer than it was originally, and facing metal still of original composition.

This wave, containing the highest amount of impurities per unit of steel, will naturally have a lower melting-point than the original steel mass. The cooling-effect of the crust will work on its outer side, and the heating-effect of the fluid central part on its inner side. If the impurities in this intermediate zone comprise enough carbon and ferrous oxide to permit their mutual reaction, we shall have:  $\text{FeO} + \text{C} = \text{Fe} + \text{CO}$ .

This reaction naturally must start where the intermediate zone is the coolest—i. e., on its outer side, next to the first solidified layer—because, the solvent power of steel for ferrous oxide increases and decreases with its purity, and also with its temperature; and this zone is one of decreasing purity and falling temperature. Here, therefore, the carbon affinity overpowers the iron affinity for oxygen, and the reaction commences, liberating carbon monoxide gas, which, unable to become absorbed by the metal, tries to escape through the still liquid steel. In its passage, it forces the mechanically absorbed hydrogen and nitrogen also out of the steel, causing a strong evolution of gas in the ingot.

We must, however, discuss the above reaction a little further. We know that the reduction of ferrous oxide by carbon is not performed without absorption of heat. Taking the atomic weights, we have: 72 ferrous oxide + 12 carbon = 56 iron + 28 carbon monoxide. That is to say, 1 lb. of carbon, oxidized to carbon monoxide, reduces 4.7 lb. of iron from ferrous oxide.

This oxidation of 1 lb. of carbon to CO, evolves 2,470 calories, while the reduction of 4.7 lb. of iron from FeO requires  $4.7 \times 1,350 = 6,345$  calories. We have, therefore, a loss of 3,875 calories for every pound of carbon thus oxidized.

The reaction which takes place in the intermediate ring—first in its outer part—between carbon and ferrous oxide, is, therefore, a strongly endothermic one, and must have a decided cooling-effect on the surrounding steel, from which it draws the heat necessary for its completion. Hence, the drop in temperature must be sharp in the intermediate ring, with the natural further consequence that the reaction between carbon and ferrous oxide must proceed very rapidly through that ring. The steel in the outer part of this intermediate ring must sud-

denly enter the pasty state, which condition will quickly be acquired by those parts facing the central part of the ingot, since it follows closely the rapid progress of dropping temperature through the ring.

Some of the evolved gases will find their way out of the steel; the rest will become entangled in the network of the pasty metal, and form blow-holes. This process will be repeated as long as the successive layers are rich enough in ferrous oxide and carbon to insure the carbon monoxide formation.

By the appearance of the blow-holes in the solid ingot we can judge how thick each intermediate ring was when the carbon monoxide formation took place; for whenever the reaction in one individual ring was over the blow-holes formed tried to close in. The blow-hole tube will therefore experience a strangulation, until the reaction, taking place in the adjacent ring, opens the blow-hole tube again to its former size—or even makes it wider than it was originally, on account of the slower passage of this next ring through the pasty state, which gives the gases more opportunity to accumulate in one place.

This cooling-effect of the reaction  $\text{FeO} + \text{C} = \text{CO} + \text{Fe}$  and its natural consequence on the formation of blow-holes, has, as far as I know, never been discussed before. I consider it of the greatest importance in the formation of blow-holes, since I believe that, all other conditions being equal, that steel will in every case form the largest amount of blow-holes which contained the greatest amount of ferrous oxide, or which, in other words, was most overoxidized.

The above-described reaction destroys the largest part of the ferrous oxide present in the intermediate ring. What is left cannot leave the solidifying steel as easily as the other impurities, since it cannot possibly coalesce as easily as the latter, and therefore cannot segregate out of the freezing metal. Being itself very refractory, it will remain finely disseminated in the solidifying steel. Ferrous oxide segregates freely in liquid steel only, not in steel approaching the freezing-point.

After the reaction between ferrous oxide and carbon is over in all those more or less wide intermediate rings which contained enough to insure it, and after blow-holes have been formed in those intermediate rings, forming together one more or less broad ring of blow-holes, another stage—namely, the

uninterrupted cooling and freezing of the central but still fluid part—can follow.

The impurities contained in the solidifying layers, and expelled by them on freezing, will again accumulate in a ring, until the reaction between ferrous oxide and carbon again becomes possible, whereupon a second ring of blow-holes will be formed in the ingot. This second ring will, however, consist of smaller individual blow-holes than the first; since the liberated gases, traveling upwards through the liquid steel, have lessened throughout its contents of occluded gases, so that the amount of gases available to form blow-holes in the second ring must be decidedly smaller than in the first. This effect proceeding from the first ring may, indeed, be so strong as to reduce the gas-content of the remaining steel until it can solidify without further blow-hole formation. In that case, the ingot will have only one ring of blow-holes.

It must be remembered, also, that the migration of the ferrous oxide, like that of the other impurities, is not only horizontal but vertical in the fluid steel, and that the steel which it left behind becomes purer and purer. However, the richer the fluid steel becomes in impurities, the lower its melting-point will drop, with the consequence, that the liberated carbon monoxide together with the other gases has continuously increasing opportunity to leave the metal.

The hotter we pour steel, the more ferrous oxide we must reckon with as contained in it to start with. The overloading of the intermediate ring with ferrous oxide will therefore occur earlier, the reaction between ferrous oxide and carbon will take place quicker, and the blow-holes formed will lie closer to the ingot-surface.

Some broken ingots which I have examined showed blow-holes without any "strangulation" rings, but with practically perfect, smooth walls. These blow-holes, which were of considerable size, although never as long as the long blow-hole tubes with "strangulation" rings, had apparently been made without any interruption. They must have been cast in one mold, as it were! When the intermediate ring has been formed, and is liable at any time to bring about the reaction between ferrous oxide and carbon, it is indeed possible that, under favorable conditions, undercooling may take place in this

ring—*i. e.*, the temperature throughout this ring may drop below that point, where under less favorable conditions carbon monoxide would have been made under all circumstances. If this undercooled ring now experiences only the slightest change in its conditions, the carbon monoxide reaction will not proceed from the outer part gradually towards the inner part, but the reaction between ferrous oxide and carbon will set in suddenly throughout the entire ring, so that the blow-holes will be formed all at once. These blow-holes will show smooth walls as the consequence of their uninterrupted formation.

The practical steel-maker knows that high-carbon as well as low-carbon steel will pour quietly, and that the ingots will be free from any dangerous blow-holes, if he is able either to prevent or to destroy overoxidation in the bath before teeming the steel. He knows also that he can bring about this state of affairs by keeping the temperature during the process well under control and getting the slag into the right condition; and he is aware that heats, which have been worked and finished too hot, will not pour quietly, and will give "spongy" steel.

The more completely we control the temperature, therefore, the more we shall be able to get steel into the molds, which solidifies solidly for a considerable period, before blow-holes are formed. The steel will have a solid crust of substantial thickness; its blow-holes will be deep-seated and hence less harmful.

Steel at a very high temperature, and containing an undue amount of ferrous oxide, is pretty hard to deoxidize successfully. If, however, the overoxidation is destroyed, such steel, although poured extremely hot, will give ingots free from blow-holes.

When steel at too low a temperature is poured into molds without being sufficiently deoxidized, blow-holes will be formed scattered all through the ingot. Here a regular ring-like solidification of the steel could not take place, as with steel of higher temperature. The segregation of the impurities is irregular—a little here, much more there—and the consequence is, that the reaction of ferrous oxide and carbon will be confined to smaller, irregularly distributed areas. That the result shows masses of blow-holes scattered without rule through the entire mass is not surprising.

Another phenomenon which I wish to mention in connection with the formation of blow-holes is the well-known appearance,

in freshly stripped ingots, of a darker lower, and a brighter upper, part. When we cut such an ingot in two, we find that in the darker lower part the blow-holes are close to the surface, while in the brighter upper part the blow-holes are much farther away. This difference is easily explained upon the foregoing theory. When the lower part of the steel begins to solidify and consequently to expel gases, the upper part will be still fluid; first, because the steel there has not been in the mold so long; and second, it is resting on the hot steel of the lower part, like a pot on an open fire, and not, like the steel in the lower part, on the heat-absorbing cold stool. The steel in the upper part has the gases partly washed out by the passage of the gases, expelled by the steel underneath. The upper part, therefore, will be much poorer in gas when it begins to solidify; the period for a quiet and undisturbed freezing will be longer; and the first blow-hole ring will lie deeper in the ingot. The closer the blow-holes are to the surface, the less metal will there be, through which the heat from the still fluid ingot-center is sent to the outside, and less heat will be conducted to the surface—hence the darker appearance of the lower ingot part. The thicker the solid ingot-crust the more heat will be conducted through the solid metal to the surface; and the more will this surface be heated—hence the brighter appearance of the upper ingot part.

The fact that the upper part of the still fluid metal inside the ingot is hotter than that in the lower part, only strengthens this difference in the appearance of the two parts.

On page 237 in his paper Professor Howe says<sup>14</sup> that under certain conditions

“ . . . the blow-holes are so large as to be harmful, and they cannot be effaced by welding, because they lie so near the skin of the ingot that their walls are oxidized by the infiltrating atmospheric oxygen, so that the contact of metal with metal, necessary to welding, is lacking. But (under other conditions) . . . the blow-holes which form are so deep-seated as to be harmless, because their sides will not be oxidized, and therefore they will weld up completely in rolling, and will thus disappear.”

With this statement that, under favorable conditions, blow-holes will weld up completely in rolling, both theoretical reasoning and practical experience render me unable to agree.

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<sup>14</sup> *Bi-Monthly Bulletin*, No. 14, March, 1907, p. 237.

The gases, which, as we have seen, fill the blow-holes in the steel ingot, stay in them from the very first moment these holes are made, until the steel is rolled, finished and ready for shipment. They are not reabsorbed by the steel; this would be impossible. Nor are they driven out of the deep-seated blow-holes. They are found even in steel which has been worked very extensively by forging down to small bars.

Drilling such forged steel, Dr. Müller found :

Volume of Gas.		Composition of Gas.	
Per Cent.	H <sub>2</sub> . Per Cent.	N <sub>2</sub> . Per Cent.	CO. Per Cent.
5.0	52.2	48.1	0.00
7.3	54.9	45.5	0.00
5.5	72.4	25.3	1.30

The composition of this gas is conspicuously similar to that of the original blow-hole gas. That the amount of gas obtained is so much less with forged steel than with unworked is quite natural, since the reduction in size by forging brings the solid and the cavity-bearing parts of the original steel block close together, so that the unit of drilled steel contains much less gas in forged than in unworked steel. Through the entire period of rolling, forging, etc., the blow-holes are filled with gas, which, being under a pressure of at least three atmospheres in the cold steel, is naturally under a much higher pressure while the steel is at the rolling-temperature. The action of rolling and stretching the steel will also stretch the blow-holes, without interfering with the contained gas, which will remain in them just as air remains in a partly-filled rubber bag, which is passed to and fro between two rollers, some distance apart.

Now, welding requires, as Prof. Howe says, the contact of metal with metal, and he points out that the oxidation of the walls of blow-holes would prevent this metallic contact. But it may be prevented by other substances as well. The gas in a blow-hole, although it may be pressed from one end to the other, as the hole becomes during rolling longer and thinner, will never permit a complete welding of the metallic walls. Small portions of them may weld together; but any weld of larger extension would certainly be severed again by the gas, which in the reduced blow-hole would naturally be under a



still higher pressure than originally, and would consequently be much more powerful to tear apart a fresh weld of the sides. The gas acts like a cushion always present, which will not permit any extended welding in even the deepest-seated blow-holes.

But besides this theoretical reason, my experience forbids me to believe in the welding of deep-seated blow-holes. The etched surfaces of many hundreds of rail sections have proved to me conclusively, that the original blow-holes are still present in the finished rail, though, of course, much smaller in diameter by reason of the rolling. The welding of blow-holes by rolling, forging, or any other operation, must therefore, in my judgment, be regarded as impossible.

#### VIII. THE PREVENTION OF BLOW-HOLES.

Having traced the causes of blow-holes, we may proceed to discuss the means by which they may be either prevented altogether, or, at least, located so deep in the ingot as to be less harmful, by reason of the presence of a surrounding mass of solid steel, thick enough to withstand the rolling without being torn apart.

Mr. Brinell's experiments and suggestions as to the proportions of manganese, silicon or aluminum in steel required to prevent blow-holes, form only a portion of the story, and will not help us very much, since by far the largest part of the daily product of Bessemer and open-hearth steel contains just that amount (in the neighborhood of 0.50 per cent.) of manganese plus silicon which he pronounces the most dangerous in this respect. As to the addition of aluminum, I must say that I have had many heats, which rolled very badly and showed all the signs of outside blow-holes, although aluminum had been added with the greatest care and discretion. On the other hand, many heats, containing the dangerous percentage in manganese and silicon, with no aluminum at all, rolled perfectly. If blow-holes could be prevented by adding a certain percentage of aluminum, the art of making sound steel ingots would lose all its difficulties—and perhaps also its interesting features!

It has been shown above, that the formation of blow-holes is not only due to the presence of hydrogen and nitrogen, but also—and not least—to the presence of ferrous oxide in the

molten metal. Indeed, we must ascribe to the presence of ferrous oxide more influence than to any other condition, since without it the liberation of hydrogen and nitrogen would always be less explosive. The entanglement of the evolved gases in the steel, when it was becoming suddenly pasty, is greatly aided by the reaction of ferrous oxide and carbon, rapidly forming large quantities of carbon monoxide, and simultaneously lowering the temperature of the steel. We know that overblown heats give porous ingots, while heats blown for a shorter time (though often only a little shorter), and presenting no more overoxidation than is effectively destroyed by the deoxidizing additions, will pour quietly and give solid ingots. Overoxidation of the steel must therefore be considered to be the chief cause of blow-holes. To prevent this defect, we must endeavor either to prevent oxidation or to destroy the overoxidation of the molten steel before it enters the molds. If we are successful in this, we may rest assured that the ingots will have only deep-seated, harmless blow-holes, if any, and that their faultless rolling into rails, plates, billets and structural material, etc., is assured.

### 1. *The Prevention of Overoxidation.*

In the Bessemer process overoxidation is prevented by guarding against blowing too hot or too long. Both will overload the steel with ferrous oxide, which cannot be completely reduced by manganese, etc., in the ladle, but will enter the molds and continue therein the reaction with carbon and the dangerous formation of carbon monoxide.

In the open-hearth process, iron-ore is usually added to assist the oxidizing influence of the flame. Iron oxides are thus brought into the bath, giving the metal every opportunity to saturate itself with ferrous oxide. To prevent too high a degree of overoxidation at the end of the heat in the open-hearth care must be taken to control the temperature of the bath and the oxidizing influence of the slag. In this process, the slag is the transmitter of the oxygen, and also the receptacle of the oxidized impurities, except the oxides of carbon. If we finish a heat with a slag too rich in oxygen, we are liable to the very last moment before tapping to the transfer of ferrous oxide from the slag into the bath. If we have, at the same time, too high

a temperature, we must expect a greater solvent power of the metal for ferrous oxide, irrespective of the carbon-content. The slag will give up ferrous oxide to the steel, which absorbs it only too readily. The bath of molten steel has a certain depth. All other conditions being equal, it will have the lowest temperature, and consequently the smallest solvent power for ferrous oxide, in its lowest layer, where it is in contact with the heat-absorbing lining of the hearth. The upper layers, close to the slag, will be the hottest, and will possess the greatest solvent power, which will be satisfied, not only by the ferrous oxide derived from the slag close at hand, but also by the ferrous oxide, which, being specifically lighter, will rise to these upper layers from the bath below. This may be easily proved, by taking two tests from the bath, one as close as possible to the bottom, and the other as close as possible to the slag. In the test-mold the steel from the lower part of the bath will solidify much more quietly, and will exhibit blow-holes to a much smaller degree, than that from the upper part.

The attainment of high temperature by the upper layers is assisted by a thick and heavy slag, which keeps the temperature back in the bath, whereas a fluid, thin slag transmits it more rapidly to the furnace and thence, with the waste gases, to the stack. It is impossible to get the bath hot enough to tap, when a very thin slag has been kept on it from the beginning. Hence, the slag must not be thinned until the bath has acquired a temperature high enough for successful tapping and pouring, and particular care must be taken to bring the slag to a high degree of fluidity. Such a slag will not allow the upper layers of the bath to take up an undue amount of ferrous oxide, since it keeps these layers from rising in temperature too far above the rest of the bath, and thus limits their solvent power for ferrous oxide.

In order to have, towards the end of the process, a slag not excessively oxidizing, care must be taken that the heat be not "over-ored," and that the last portion of ore added be perfectly "boiled out" before tapping. I have had opportunity to make many open-hearth heats with Swedish magnetite in large lumps. Proper care being taken in working down and finishing the heats, no trouble whatever was experienced with the resulting ingots. At other times, I had to use so-called "con-

centrate" from Sweden—a fine, sand-like magnetite, the product of magnetic separation. In operating with this fine ore, besides taking much more time to bring down the carbon of the bath to the point required, I got extremely bad steel, full of blow-holes. This indicated that slag still rich in oxygen when the heat is ready to tap (as was the case with the fine magnetite concentrate) tends to the formation of overoxidized steel, and hence of blow-holes.

To prevent overoxidation in the open hearth, care must therefore be taken :

(k) That the temperature during the process be kept not too high.

(l) That the slag be maintained in a good, thin condition during the latter part of the process.

(m) That the oxidizing power of the slag be brought to a minimum towards the end of the process.

But, though all these prescriptions be piously fulfilled, it will nevertheless be impossible to manufacture steel without any overoxidation at all. The solvent power of molten steel for ferrous oxide is so great that some of the oxide will be dissolved in the metal, in spite of all possible precautions. We must, therefore, reckon with a certain, unavoidable degree of overoxidation in all steel, and the next problem is therefore :

## 2. *The Destruction of Overoxidation.*

We have seen that when a stirring-rod is moved to and fro in the bath, a strong evolution of carbon monoxide takes place. Since this is just what we desire, we certainly should continue stirring until the wave over the rod has more or less completely subsided. This stirring of the bath, shortly before tapping, is greatly beneficial in lessening overoxidation in the steel, and should be more general than it is in present practice. Any addition to the bath of substances which combine easily with oxygen will naturally assist the destruction of overoxidation.

Spiegel, ferromanganese or pig-iron (cold or fluid) will thus add carbon and manganese, both of which will combine with oxygen all the more easily, since their solution and the consequent reaction with ferrous oxide are accompanied with a lowering in the temperature of the bath. While the carbon monox-

ide thus formed is escaping as a gas, the manganese protoxide will be taken into the slag; and there it will stay, unless the slag be so rich in manganese as to permit its reduction and return to the bath. But such a continuous reduction of manganese from the slag would decidedly aid in lessening overoxidation in the bath; and therefore it would be advisable to secure, in the open-hearth furnace, slags rich in manganese, if manganese (in any form) were not so expensive.

As to the deoxidizing influence of the silicon brought in by ferrosilicon, it may be said that silicon by itself will destroy overoxidation, but that such deoxidized steel will not be free from red-shortness. Only when manganese is present, besides silicon, will the red-shortness of the steel disappear.

### 3. *Heat-Finishing in the Ladle Versus Heat-Finishing in the Furnace.*

It is the general custom in this country to deoxidize the steel in the ladle, while in many European works this practice is not regarded as safe, and the steel is deoxidized in the furnace before tapping. All other conditions being the same, deoxidation in the furnace is unquestionably better than in the ladle. The deoxidizer, added to the bath in the furnace, will float, partly submerged, on the metal; will dissolve there; and will therefore deoxidize just that portion of the bath which is most overoxidized. The only drawback is, that a part of the added manganese, etc., will be lost into the slag, which, by reason of its oxygen-content, is only too eager to seize upon the manganese, etc., and will thus deprive the bath, for which the addition was intended, of part of its deoxidizing supply. To counterbalance this loss, a certain surplus of the deoxidizer must be added, when deoxidation is performed in the furnace.

Deoxidation in the ladle, on the other hand, is generally satisfactory, unless the degree of overoxidation in the steel is unusually high. But in that case most of the deoxidizer will already be dissolved, before that portion of the bath gets into the ladle, which needs deoxidation the most—namely, the upper layers. The ferrous oxide of this portion, on reaching the ladle, will find the deoxidizer present, not in concentrated form and therefore most efficient, but already dissolved and strongly diluted in the large mass of molten steel. The

reactions between carbon, manganese, silicon and ferrous oxide are then necessarily more sluggish, require more time. It is possible that, in such cases, the steel may enter the molds, without having been properly deoxidized, and may consequently form dangerous blow-holes in the ingots. Another drawback to ladle-deoxidation is, that the manganese protoxide and silicate thus formed may often have too little time to separate into the slag before the steel reaches the mold and solidifies therein. The ingot may then contain small, but nevertheless dangerous, inclosures of slag (*i. e.*, manganese protoxide and silicate), which will make the steel "short" and brittle.

#### X. THE INFLUENCE OF CARBON, MANGANESE, SILICON AND ALUMINUM IN STEEL TOWARDS THE PREVENTION OF BLOW-HOLES.

Iron with at least 2.3 per cent. of carbon and various amounts of other impurities, such as manganese, silicon, phosphorus, sulphur, etc., is classed as pig-iron. It is distinguished chemically from steel (or ingot-iron) by the higher percentage of these impurities, especially of carbon. We have seen that iron in the molten state is able to absorb gases, and to expel them again on freezing. The amount of gases taken up by iron in the blast-furnace probably depends on the pressure in the hearth of the furnace, the degree of superheating in the hearth, the percentage of silicon in the metal, the melting-point of the iron and the slag, and the percentage of moisture in the blast.

The more gases the iron was able to absorb, while in the blast-furnace, the more it will try to set free, when solidifying, so far as its degree of fluidity will permit. The more fluid the metal, the more gases it will allow to escape. The thicker the iron, the more gases will stay in it and the greater the possibility of blow-holes. Iron made during a cold, irregular run of the blast-furnace generally flows very thickly, and exhibits many blow-holes. Tables III. and IV. illustrate these propositions.

TABLE III.—*Composition of Gases Escaping from Molten Iron.*<sup>15</sup>

	H <sub>2</sub> . Per Cent.	CO. Per Cent.	CO <sub>2</sub> . Per Cent.	O <sub>2</sub> . Per Cent.
(a) Foundry iron, thick and mushy, average from 13 analyses, . . . . .	6.4	4.5	8.6	0.5
(b) Basic iron and spiegeleisen, thin and fluid, average from 48 analyses, . .	21.9	19.1	1.3	0.4
(c) Foundry iron, very thin and fluid, aver- age from 6 analyses, . . . . .	47.3	13.7	1.3	0.5

TABLE IV.—*Composition of Gases Obtained by Drilling Solid Foundry Iron.*

Size of Bore-Hole. cc.	Gas Obtained Under Ordinary Pressure. cc.	Composition. H <sub>2</sub> . Per Cent.	Composition. CO. Per Cent.
61	26.2	57.6	0.7
55	16.6	42.2	1.9
61	31.6	59.0	0.9
58	47.6	66.1	0.6
48	17.0	59.0	3.5
55	32.2	46.2	1.2
53	31.2	56.7	1.3
65	74.8	43.6	0.3
55	76.6	67.3	0.2

Why is it that pig-iron, although absorbing in the molten state large amounts of gases, has not, by far, so great a tendency to form blow-holes as steel or ingot-iron?

To answer this question correctly we must find out whether the same conditions as to the formation of carbon monoxide exist in pig-iron as in steel and ingot-iron. We know, now, that molten iron increases in solvent power for ferrous oxide—the source of carbon monoxide—with rising temperature and growing degree of purity, and that, on the other hand, the affinity of carbon for oxygen lags behind that of iron the higher the temperature rises. In pig-iron, the melting-point of which is considerably below that of steel (especially low-carbon steel), the solvent power for ferrous oxide must naturally be decidedly smaller than in steel. Hence, in approaching the freezing-point, pig-iron cannot form as much carbon monoxide as steel can. The solidification of pig-iron, therefore, is accompanied, not by a sudden, but only by a quiet, liberation of absorbed gases, which continues until the iron is solid.

That molten pig-iron is able to dissolve some ferrous oxide,

<sup>15</sup> E. Munker, *Stahl und Eisen*, vol. xxiv., p. 23 (1904).

which in cooling reacts with carbon to form carbon monoxide, will be seen from the analyses given above. It may be asked, why this carbon monoxide, even though less abundant than in cooling steel, does not cause the formation of blow-hole rings in the solidifying iron—consisting perhaps of smaller individual blow-holes, but present nevertheless! The answer is found in the sudden passage of pig-iron from the molten to the solid state, without first becoming pasty. It is the pasty steel, as we have seen, which entangles the liberated gases in its rapidly growing network, and (since it is pasty and can therefore be pushed aside somewhat) allows the small bubbles of liberated gases to accumulate in large blow-holes. Pig-iron does not know such a pasty state; it does not, therefore, catch the liberated gases and prevent them from escaping, but stays fluid until the last moment, when it becomes solid. The liberated gases can therefore escape during the entire period of approach to the freezing-point, and no intermediate pasty state holds them back in the metal before the freezing-point is reached. Those gases which are set free, in greater or smaller quantity, at the very instant of freezing can never give blow-holes, either in pig-iron or in high- or low-carbon steel. They will remain finely disseminated through the entire mass of metal.

The reasons why pig-iron does not form blow-holes on freezing are therefore :

- (n) Its low solvent power for ferrous oxide;
- (o) The absence of a pasty state, between the molten and solid, states.

We may now more easily understand the preventive influence of carbon, manganese and silicon on the formation of blow-holes. All these elements, single or combined, lower the melting-point of the iron, which therefore becomes fluid at a lower temperature. As to the degree of overheating, carbon especially will not allow the metal to overstep a certain temperature in the furnace. It is, in the open-hearth, the true temperature-regulator, unerringly and immediately acting, when the temperature of the bath is unduly high, by increased oxidation and consequently lowering of the temperature. Carbon and temperature of the bath must always be in equilibrium. The more carbon, therefore, the steel contains the lower will be its



melting-point and its temperature, and consequently its solvent power for ferrous oxide. But the less ferrous oxide the steel contains, the more certain will be its successful destruction by deoxidizing additions, and the smaller the danger of blow-holes. Moreover, carbon, just like silicon and manganese, tends to shorten the pasty state of the solidifying steel, thus giving more time and opportunity for the escape of gases before solidification. For this reason it is extremely difficult to cast steels low in carbon, manganese and silicon into ingots which do not contain broad rings of blow-holes. Steels high in carbon, manganese or silicon stay perfectly fluid much longer; the pasty state is considerably shortened, and the danger of blow-holes decidedly lessened.

By adding carbon, manganese and silicon, in the furnace or in the ladle, we endeavor to destroy the ferrous oxide present in the metal. This destruction is assisted by the increasing affinity for oxygen which these elements acquire with falling temperature (while that of iron decreases simultaneously), and also by the lowering of the melting-point of the metal, which permits them to act with increasing intensity. To deoxidize steel of excessively high temperature is, therefore, extremely difficult; every steel-maker knows that. Only when the steel has the right medium temperature can he be sure of success; and the natural consequence is, that he avoids pouring steel too hot into the molds, knowing that it will still contain ferrous oxide, in spite of the deoxidizing additions previously made. The temperature of the steel when it enters the mold governs its later behavior therein. If it be too hot, and consequently still have ferrous oxide dissolved in it, the reactions between this compound and carbon, manganese and silicon will continue while the metal is approaching its freezing-point in the mold, and the formation of blow-holes is inevitable. Only when we tap the heat at the right temperature, or when we wait until an excessively hot heat has cooled down in the ladle, so that we pour at a good, medium temperature, can we be successful in our endeavor to destroy overoxidation in the steel before it enters the mold.

Aluminum, like carbon, manganese and silicon, shortens the pasty stage and lowers the melting-point of the cooling steel. Like them, also, it destroys ferrous oxide by reducing it to metallic iron. It is much stronger in this action than man-

ganese. One part of manganese reduces 1.8; one part of aluminum reduces 4.0; and one part of silicon reduces 5.14 parts of ferrous oxide. Hence, aluminum, added to the steel with the necessary care and discretion, would be a much better deoxidizer than manganese. But to add aluminum in the mold, when it is practically filled to the top, has no influence on the metal underneath. The upper layers of steel in the mold, becoming perfectly deoxidized by the added aluminum, will instantaneously become quiet. No gases will escape vigorously from these upper layers, and no fresh and hot steel will consequently rise continuously to the surface, keeping the ingot there open. The quiet surface-metal, losing its heat rapidly, will quickly solidify and give a solid ingot-top. But underneath, in the still fluid steel, carbon monoxide gas will continue to form, and will liberate hydrogen and nitrogen in considerable quantities. Instead of escaping from the ingot, these gases are kept back in it, so that, in the slowly solidifying steel underneath, many blow-holes are formed. A continuous addition of small quantities of aluminum to the steel while pouring it into the mold has the decided disadvantage that the alumina thus formed has no time and no chance to separate out on the surface. The formation of carbon monoxide, and with it the separation of hydrogen and nitrogen, stops practically altogether, so that the alumina molecules find no assistance to rise to the surface of the ingot. They remain in the steel and make it short and brittle, which is practically as bad as to have dangerous surface blow-holes.

The only place to add aluminum is in the ladle. Here it can do its beneficial work in destroying the ferrous oxide in the steel, while the resulting alumina has time and opportunity to rise through the fluid steel to the surface and to become harmless.

The often heard explanation that silicon and aluminum render the steel more porous for occluded gases, and thus prevent the formation of blow-holes, seems to be not only far-fetched, but also incapable of proof. I consider it better to explain the action of these two elements from a purely chemical and thermal standpoint, as I have done above.

Aluminum absorbs gases (hydrogen) when in the molten state. J. W. Richards<sup>16</sup> found that molten aluminum will absorb

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<sup>16</sup> *Aluminium: Its History, Occurrence, Properties, etc.*, 2d ed., p. 56 (1890).

large quantities of gas, which is set free again when the metal solidifies. M. Dumas found in 200 g. of solid aluminum, occupying 80 cc., when heated *in vacuo*, 89.5 cc. of gas measured at 17° C. and 75 mm. pressure. The gas consisted of 1.5 cc. carbonic acid and 88 cc. hydrogen. Since aluminum takes up gases itself, when molten, it must favor the absorption of gas by steel, when present therein.

#### X. THE PREVENTION OF BLOW-HOLES BY INCREASE AND DECREASE OF PRESSURE.

Experience of our daily life teaches us that a fluid is able to absorb and keep in solution more gas when under pressure. A closed bottle filled with mineral water or champagne keeps the liquid under quite a pressure, due to the disengaged carbon dioxide in the bottle, which presses on the liquid. No sign of carbon dioxide can be observed in the liquid, even when we shake the bottle vigorously. As soon, however, as the bottle is opened the pressure is released, and a strong evolution of carbon dioxide all through the liquid takes place. Slowly the liberation of gas subsides, and after some time ceases altogether. If we now connect the bottle with a suction-pump and form a partial vacuum over the liquid, a vigorous renewed liberation of carbonic dioxide will take place. In the same way, water which has ceased to boil will strongly boil again without further supply of heat when placed in a partial vacuum. According to Bunsen, for the same gas, the same liquid and the same temperature, the weight of gas absorbed is proportional to the pressure.

Molten iron behaves in this respect like a true liquid, and is therefore able to keep more gases in bond under higher, than under ordinary atmospheric, pressure. Hence all processes and arrangements which put solidifying steel under pressure tend to prevent the formation of blow-holes. In such a freezing steel the point of solidification is raised in accordance with the pressure; *i. e.*, the liquid steel becomes solid sooner under pressure than under ordinary circumstances. This more rapid passage from the liquid to the solid state must necessarily shorten the intermediate pasty state, and thus hinder the formation of blow-holes. In steel, cooling under pressure, the ferrous oxide will be only partly destroyed by carbon, the time

of this reaction being shortened. Hence, less carbon monoxide is formed and a smaller quantity of other gases is forced out by the escaping carbon monoxide. Steel solidifying under high pressure will therefore exhibit but few blow-holes. The gases did not have time to accumulate and to form large bubbles, but remained finely disseminated through the entire mass of steel.

The "Whitworth," "Illingworth," "Harmer" and "Williams" processes, described in Professor H. M. Howe's paper, will therefore give steel comparatively free from blow-holes.

Molds which, like the so-called "bottle-top" molds, are so constructed that the rising steel must soon press against a rigidly closed top, will give, under favorable conditions, ingots with less blow-holes than "open-top" molds, which generally are not capped until the steel has solidified somewhat around the edges of the top. Arrangements to exert a pressure on the solidifying steel in the mold, by filling the space between ingot-top and mold-cap with steam or carbon dioxide and thus to get ingots free from blow-holes, have been tried extensively in this country as well as in Europe. So far as I am aware, however, they are nowhere used to-day.

The same effect as that of increased pressure in preventing blow-holes would be obtained if the pressure over the liquid or solidifying steel should be reduced. In that case, the gases would be able to escape in much larger quantity than under ordinary pressure; the remaining steel would experience a considerable diminution of its gas-content, and blow-holes would consequently be less liable to form. Moreover, the reduced pressure would lower the melting-point, keeping the metal fluid for a longer time, and would consequently assist the escape of gases.

## XI. OTHER ARRANGEMENTS AND PROPOSITIONS TO PREVENT BLOW-HOLES IN STEEL INGOTS.

Starting from the idea that any liquid, containing occluded gases, will release them when stirred thoroughly, W. D. Allen, of Sheffield, England, employed an apparatus by which he stirred the steel in the ladle. The results were very encouraging; the steel thus stirred gave sound ingots, free from blow-holes. This idea, however, did not have any extended adop-

tion by other steel-plants, owing very probably to the fact that such a stirring necessarily requires a very hot steel, or else a heavy skulling of the stirring-arms will quickly take place. F. Knaffl<sup>17</sup> proposed to shake the mold immediately after pouring, by raising a little the stool on which the mold rests and dropping it again on a solid support. Such a shaking of the steel must certainly be of assistance to the escaping gases; the metal will solidify with less blow-holes than if allowed to set undisturbed.

A number of schemes for pouring steel in a partial vacuum were patented years ago, but, so far as I know, never tried in practice. The evacuation of the converter, after the heat is blown, has been proposed by W. Durfee and N. B. Wittmann.

Sink-heads, kept fluid for some length of time, either by making the upper part of the mold less conductive of heat, or by heating the sink-head with coke, gas or electricity, will also allow more gases to escape from the steel and will therefore assist in the prevention of blow-holes. Such sink-heads are used for the prevention of pipes in steel ingots, and ingots thus treated will doubtless be also improved as to blow-holes.

The idea, introduced by Boulton, of pouring a continuous ingot by putting always a new "open-top" mold on the already partly filled mold, and thus getting ingots free from blow-holes, has been in practical use at the West Bergen steel-works. The steel in the lower molds had opportunity to release the largest amount of its liberated gases through the still fluid metal above, with the consequence, that in the solidifying steel but a small quantity of gas was left, which was unable to form blow-holes of appreciable size and number.

The use of centrifugal force for degasifying liquid steel has been, and still is, employed in the manufacture of car-wheels. The very great difference in the specific gravity between liquid steel and gas must force the latter out of the molten metal, when put under the influence of centrifugal force. No doubt the centrifugal treatment of liquid steel before it enters the molds would greatly assist in the manufacture of ingots free from blow-holes.

To sum up: the means for the prevention of blow-holes in steel ingots are :

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<sup>17</sup> German patent No. 48,874, and British patent No. 5,639 (1889).

1. Medium temperature of the heat during the last period of the process in the converter or open-hearth.

2. Careful avoidance of overblowing or over-oreing of the heat; careful boiling-out of the last portion of ore added to the bath.

3. A finishing slag, not too rich in oxygen and having the proper degree of fluidity.

4. The destruction, by stirring the heat before tapping, of the ferrous oxide formed.

5. Addition of sufficient deoxidizing material to the heat, and the allowance of sufficient time for the complete separation of the manganese protoxide, silicate of manganese or alumina, thus formed, into the slag.

## XII. THE DAMAGE DONE BY BLOW-HOLES IN STEEL INGOTS.

We must distinguish between deep-seated blow-holes and those which lie beneath the ingot-skin. While the former are practically harmless, since they are not affected by the oxidizing influence of the atmosphere, and will not cause scrap in rolling, the latter are decidedly harmful and dangerous, when they are arranged so closely to the ingot-surface that they are affected by the oxidizing influence of the atmosphere, and render the ingot-surface so weak that it cannot withstand contraction, or that it is torn apart in rolling.

These dangerous blow-holes must be prevented, since they are doing all the damage to the ingot, while solidifying in the mold and in rolling.

An ingot, containing a broad ring of blow-holes close to the skin, will naturally be much weaker here than when the skin consists of solid steel of considerable thickness. The ingot, contracting in the mold, while cooling down, will already be quite cool and solid in the four corners, while the four sides, especially in the middle, are still very hot and much less solid than the corners. Contracting, the ingot will exert a tension on these sides, since it cannot yield in the corners, where naturally great friction exists between ingot and mold. The weaker the solid skin of the ingot has been made by blow-holes, arranged directly underneath, the less it can withstand the heavy pull of the contracting steel, and the easier the ingot surface will therefore be torn apart.

The same will happen when the steel, by running between stool and mold, forms a fin of solid metal at the bottom of the ingot. The steel contracts not only sideways, but also vertically. At the bottom the fin prevents the free contraction, while in the upper part the ferrostatic pressure crowds the still plastic steel close to the walls of the mold, causing thereby heavy friction between ingot and mold. The ingot-surface must consequently crack. But even when there is no fin of solid steel at the bottom of the ingot its surface may crack, since the ingot, while pressed against the walls of the mold in its upper part, may hang itself up in the mold, due to the contraction of the lower part. If the ingot-skin is weakened by dangerous blow-holes, very deep and bad cracks may develop. Such cracks generally lie in the upper part of the ingot, and are more likely to occur in "bottle-top" than in "open-top" molds.

Blow-holes which are separated from the outside air by a very thin solid skin only, will often open up in the soaking-pit. Here the already thin skin is still more reduced by the formation of scale on the ingot, while the heating expands the gases in the blow-holes, so that they may break through. Such ingots, coming out of the soaking-pit, will look pitted. Many blow-holes have been opened, and the air, coming in contact with the sides of these blow-holes, will oxidize them. Even when the blow-holes are still covered with a thin layer of steel, the rolling will easily tear apart this thin solid surface, and many fine (often, indeed, large) cracks will appear on the blooms. These cracks, at first straight, will by and by become V-shaped; their sides will overlap; and the finished product will show "snakes" and "flaws." Dangerous blow-holes, lying close beneath the ingot-surface, will therefore be the chief cause of scrap in the rolling-mill and the rejections in rail-plate and other mills.

The prevention of such blow-holes, even at considerable expense, will pay for itself by lowering the percentage of scrap and "seconds," and improving the quality of the finished products.

## The Present Source and Uses of Vanadium.

BY J. KENT SMITH, PITTSBURG, PA.

(Toronto Meeting, July, 1907.)

VANADIUM is generally spoken of as a rare element; but, even in the light of our resources as known a couple of years ago, this description could be accepted in a qualified sense only. In fact, vanadium is very widely distributed, being a constituent of most clays, while even caustic soda has been shown to contain almost regularly a minute proportion of it, although the quantity in each case is so small as to render impracticable the extraction of the metal therefrom with profit.

The opening-up of a large deposit of vanadium sulphide ore in South America has put a new phase on the commercial outlook of vanadium, the technical value of which for the improvement of steel has been proved by rigorous scientific investigation.

This sulphide ore has the following analysis:

	Per Cent.
Vanadium sulphide, . . . . .	39.84
Molybdenum sulphide, . . . . .	1.57
Nickel sulphide, . . . . .	1.49
Iron sulphide, . . . . .	4.07
Arsenic sulphide, . . . . .	nil.
Copper sulphide, . . . . .	nil.
Manganese sulphide, . . . . .	nil.
Free sulphur, . . . . .	30.57
Phosphorus, . . . . .	nil.
Silica, . . . . .	13.60
Alumina, . . . . .	2.46
Combined water, }	
Carbonic acid, }	5.00
Lime, magnesia, potash, soda }	
and unaccounted for, }	1.40
	100.00

Being a free-burning ore it is calcined with ease, losing 45 per cent. of its weight in the process. The calcined ore has the following analysis:



	Per Cent.
Vanadic oxide ( $V_2O_5$ ), . . . . .	58.08
Iron oxide, . . . . .	4.98
Molybdenum oxide, . . . . .	2.62
Nickel oxide, . . . . .	2.24
Arsenic oxide, . . . . .	nil.
Copper oxide, . . . . .	nil.
Manganese oxide, . . . . .	nil.
Phosphoric acid, . . . . .	nil.
Silica, . . . . .	25.00
Alumina, . . . . .	4.52
Lime, magnesia, potash, soda, etc., . . . . .	2.56
Sulphur, . . . . .	0.23 per cent.
	<hr/> 100.00

The deposit is situated in Peru, South America; mining conditions are easy, and the ore is transported to the port of Callao by direct railway-communication extending almost the entire distance. The vanadium claims have an area of 5.25 sq. miles, being 3.5 miles long by 1.5 miles wide. A large proportion of this area is vanadiferous, some probably owing to the impregnation of the aluminous earth by solutions of oxidized vanadium. Five distinct veins of large dimensions have already been proved on the property. The vein at present being worked has a width of 16 ft., and has been opened up on the face for a distance of 200 ft.; this vein dips at an angle of  $65^\circ$ , and by means of driving a tunnel lower in the face of the hill its existence in its pristine richness has been proved 140 ft. back. The working is done by means of "levels."

Previously the most commercial sources of vanadium at our disposal were the Spanish lead-ores. These, as mined, contain only 4 or 5 per cent., but by primitive processes of hand-dressing could be concentrated so that the "heads" contain, say, 12 per cent., of vanadic oxide. An analysis of this class of ore (vanadinite) is as follows:

	Per Cent.
Vanadic acid, . . . . .	11.49
Lead oxide, . . . . .	34.15
Lead sulphide, . . . . .	1.43
Ferrous oxide, . . . . .	13.17
Manganese oxide, . . . . .	0.77
Zinc oxide, . . . . .	0.62
Molybdenum oxide, . . . . .	trace
Calcium carbonate, . . . . .	0.74
Siliceous matter, . . . . .	35.67
Silver, . . . . .	3.5 oz. per ton.

The ore usually contains a little more lead and less siliceous matter, and, in addition to the components shown, my invariable experience has been that such ores contain copper, arsenic and phosphorus. Sometimes the percentage of copper rises considerably; *e.g.*, in chileite we have:

	Per Cent.
Vanadic oxide, . . . . .	13.50
Lead oxide, . . . . .	54.90
Lead chloride, . . . . .	0.30
Copper oxide, . . . . .	14.60
Arsenious oxide, . . . . .	4.60
Phosphoric acid, . . . . .	0.60
Sand and clay, . . . . .	2.00
Iron peroxide, alumina, etc., . . . . .	3.50
Lime, . . . . .	0.50
Loss in ignition, . . . . .	2.70

A much rarer mineral, descloizite, containing a considerable amount of maganese in place of the copper, has been found in a crystallized condition and in comparatively small quantities. Its analysis shows:

	Per Cent.
Vanadic oxide, . . . . .	22.46
Lead oxide, . . . . .	54.70
Zinc oxide, . . . . .	2.04
Copper oxide, . . . . .	.90
Manganous oxide, . . . . .	5.32
Manganese dioxide, . . . . .	6.00
Sand and clay, . . . . .	3.44
Iron peroxide, alumina, etc., . . . . .	1.50
Loss in ignition, . . . . .	2.20

On comparing these analyses, the value of the sulphide-deposit will be seen at once; since, in addition to the practically inexhaustible quantity of the mineral obtainable, its richness and the comparative ease with which the vanadium can be separated (as opposed to the separation of smaller quantities from complex ores, the treatment of which involves the removal of lead, copper, arsenic, phosphorus and zinc in addition to the siliceous gangue), make it a great commercial consideration.

Vanadium is a silvery white metal of high melting-point—said to be 2,000° C., and, at all events, higher than the melting-point of platinum—so that its commercial use in the metallic form is practically restricted to its use as a refractory metal (in the filaments of electric lamps, for instance). An alloy of iron with vanadium in the proportion of two parts of iron to one part of

vanadium has a melting-point of  $1,375^{\circ}\text{C.}$ , or one more than  $100^{\circ}\text{C.}$  below that of mild steel; and it is in this form that the metal is marketed for the use of the steel-maker.

The old custom of judging a steel by its resistance to static load, and the amount it would stretch under such load, gave a certain general guide as to the behavior of metal under conditions of engineering practice which are now rapidly being left behind. Even under these conditions, mysterious failures occasionally occurred, which, it is now evident, had their origin in the inability of the metal to resist strains applied in a totally different manner from that in which it was tested.

As the requirements of modern engineering construction became more and more drastic respecting the power of resistance to rapidly-repeated strains and shocks, accompanied, of course, by increased demands as to actual strength, the old test-conditions were still further receded from in practice; and it became necessary to resort to alloy-steels.

Here some success was scored; but the true requirements were nevertheless lost sight of, and the metal was still judged almost entirely by its behavior under static loads. With the same ductility, an increase in the strength was looked upon as the one desirable thing, although it is now recognized that this improvement in strength, if attained at the expense of dynamic properties in the original steel, is, in most cases, of comparatively little use to the engineer. In short, we lost ourselves in straining after something which we did not want, and which we attained only at the expense of something we did want.

Since, in modern machine-construction, and especially in those parts which are liable to failure in use, we require, above all, superior resistance to repeated stresses, to alternating stresses, to simple, repeated or alternating impacts, and to fatigue (which is the outward and visible sign of intermolecular vibratory deterioration), a new field has been opened, and in this field vanadium has been found, by extended experiment and practical experience, to be uniquely valuable. As to static properties, vanadium intensifies greatly the strengthening effect of another ingredient, such as chromium, thus enabling the proportion of the latter to be so reduced as to avoid "poisoning" the metal with regard to desired dynamic qualities. Moreover, vanadium is itself highly contributory to the dynamic excellence of mild

TABLE I.—*Properties of Vanadium Steel Compared with Some Other Steels.*

Test.	For Comparison.		For Comparison.		Dynamic.		Combined.		Static.		Nature.
	1. Carbon 'Axle' Steel.		2. Nickel 'Axle' Steel.		3. Vanadium Axle Steel.		4. Vanadium Crank-shaft Steel.		5. Vanadium Continual Mesh Gear Steel.		
Yield-point, lb. persq. in.....	41,330		49,270		63,570		110,100		224,000		Static.
Ultimate stress, lb. per sq. in..	65,840		87,360		98,080		127,800		232,750		
Ratio.....	0.62		0.56		0.66		0.87		0.96		
Contraction of area, per cent..	61		58		61		58		39		
— Elongation, per cent. on 2 in... — Torsional twists.....	42		34		33		20		11		Inter- mediate.
	2.6		3.2		4.2		2.5		1.8		
Alternating bends .....	10		12		18		10		6		
Pendulum impact, ft.-lb.....	12		14		16.5		12		6		
Alternating impact. } Number of stresses. }	960		800		2,700		1,850		800		Dynamic.
Falling weight on notched bar } Number of blows. }	25		35		69		76		.....		
Rotary vibrations } Number of revolutions. }	6,200		10,000		67,500		.....		.....		

steel. By retarding segregation, it renders the metal particularly susceptible to enormous improvement by tempering and heat-treatment generally. By virtue of this characteristic, steel can be "automatically" rendered highly resistant to wear and abrasion. Again, vanadium toughens steel; confers upon it great power of resistance to torsional rupture; in a word, endows it with increased "life" in practical use.

Being a powerful "medicine," vanadium is used in small doses only. In engineering-steels, the maximum proportion required seldom exceeds 0.2 per cent. By its judicious use, combinations are thus made possible which could not be formed without it, and which permit the successful fulfillment of complicated requirements, whether chiefly static, chiefly dynamic, or divided more or less equally between the two classes.

These varying and partially contradictory demands must all be considered, in order to meet modern conditions; and vanadium is the only substance yet known to us, by means of which they can be successfully satisfied. How it meets them is shown in Table I., which contrasts the properties of vanadium steel with some other steels. The data presented in this table were obtained under like conditions of testing.

The great industrial importance of vanadium being thus evident, the question of its commercial supply becomes a vital one. As already observed, it was, until recently, classed among the "rare" metals, not because it was not known to be widely distributed, but because it could be profitably produced in few localities and small quantities only. The development of the large deposit of rich vanadium sulphide, above noted, and the erection in Pittsburg, Pa., by the American Vanadium Co., which owns that mine, of works having a daily capacity of 2,000 lb. of vanadium-alloys, settles the question of commercial supply.

In the preparation of these brief notes, I am indebted to Mr. J. O. Handy, of Pittsburg, for assistance in analytical work.

## **The Effect of High Litharge in the Crucible-Assay for Silver.**

BY RICHARD W. LODGE, BOSTON, MASS.

(Toronto Meeting, July, 1907.)

IN the crucible-method of assaying ores for silver a certain amount of litharge is essential to supply sufficient lead to collect the precious metals. The object of this paper is to point out that the use of a large excess of litharge in the assay of some ores will give results for silver that are uneven as well as low. So far as I know, however, an excess of litharge does not affect the results obtained in the crucible-assay of ores for gold.

The main reasons for using, in the crucible-assay, much more litharge than is required to give the necessary lead button are: 1, its action as a flux; 2, its action as a desulphurizer; and 3, its action as an oxidizer, especially on metals like copper and nickel, whereby they are forced into the slag as oxides and thus prevented from passing into the lead button.

Hence, by the use of much litharge in the crucible-assay more ore can often be taken than in the scorification-process, and a lead button obtained which can possibly be cupelled at once or after a single scorification. The method is specially advantageous with an ore carrying much copper or similar impurity and poor in silver, when the assayer does not wish to resort to a wet-analysis for the determination of the silver.

It is well known that some ores give better results when assayed by the scorification-method, while others give better results by the crucible-method.

For several years I have noticed that, when much litharge was used with certain sulphide and arsenical ores, the results were considerably lower than when the scorification-method was used.

This fact was more forcibly brought out in connection with certain work carried on this year by Messrs. H. A. Frame and

F. C. Jaccard, students at the Massachusetts Institute of Technology, to ascertain the best method of assaying the rich arsenical nickel- and cobalt-ores from Ontario, Canada.

The following are some results obtained: Ore No. 2,687-2 had a reducing-power of 4.2 and contained Ni, 12.92; Co, 10.92; and As, 46 per cent. The minerals noticed in the ore were niccolite, smaltite, erythrite, cobaltite and arsenopyrite.

Charge for the Crucible.					Results.		
Ore.	Sodium Bicarbonate.	Borax-glass.	Litharge.	Argols. (R. P. = 11)	Lead Button.	Silver Found.	Silver in Slag.
	g.	g.	g.	g.	g.	Oz. per Ton.	
$\frac{1}{10}$ A. T.	10	5	30	$1\frac{1}{2}$	23	0.11615 2323	Not assayed.
$\frac{1}{10}$ A. T.	10	10	35	$1\frac{1}{2}$	23	0.11648 2329.6	Not assayed.
$\frac{1}{10}$ A. T.	10	5	80	$1\frac{1}{2}$	28	0.11272 2254.4	52.4 oz.

Ore No. 2,687-6 consisted chiefly of smaltite, erythrite, niccolite and arsenopyrite; R. P. = 4.06; Ni, 3.94; Co, 11.25; and As, 59.7 per cent.

Ore.	Sodium Bicarbonate.	Borax-glass.	Litharge.	Argols.	Lead Button.	Silver.
	g.	g.	g.	g.	g.	Oz. per Ton.
$\frac{1}{10}$ A. T.	10	10	35	1.5	22	258.2
$\frac{1}{10}$ A. T.	10	10	80	1.5	21	241.2

The same ore assayed after amalgamation:

$\frac{1}{10}$ A. T.	30	10	30	1.5	23	229.8
$\frac{1}{10}$ A. T.	10	10	35	1.5	23	230.8
$\frac{1}{10}$ A. T.	10	10	80	1.5	23	220.2

Subsequent to the above tests I made further investigations on the ores tested as well as on other ores and obtained the following results: Ore No. 2,687-2; R. P. = 4.2; Ni, 12.92; Co, 10.92; and As, 46 per cent.

Scorification-Method.—Charge.				Results.	
Ore.	Borax-glass.	Lead.	SiO <sub>2</sub> .	Lead Button.	Silver.
$\frac{1}{10}$ A. T.	g. 3	g. 65	g. 1.5	g. 11	Oz. per Ton. 2330.4
$\frac{1}{10}$ A. T.	5	65	1.5	10	2338

Crucible-Method.						
Ore.	Sodium Bicarbonate.	Borax-glass.	Litharge.	Argols. (R. P. = 11)	Lead Button.	Silver.
$\frac{1}{10}$ A. T.	g. 10	g. 6	g. 35	g. 1.5	g. 22	Oz. per Ton. 2333.2
$\frac{1}{10}$ A. T.	10	6	35	2	30	2330.8
$\frac{1}{10}$ A. T.	10	6	80	1.5	23	2229.2
$\frac{1}{10}$ A. T.	10	6	100	1.5	25	2244.2

Ore A. Chiefly smaltite and niccolite with free silver, containing Ni, 5.06, and Co, 9.12 per cent.

Ore.	Sodium Bicarbonate.	Borax-glass.	Litharge.	Argols.	Lead.	Silver in Lead. Oz. per Ton.	Silver in Slag. Oz. per Ton.	Silver in Cupel. Oz. per Ton.
$\frac{1}{10}$ A. T.	g. 10	g. 10	g. 30	g. 1.5	g. 19	2051.4	9.6	34.0
$\frac{1}{10}$ A. T.	10	10	40	1.5	21	2056	.....	.....
$\frac{1}{10}$ A. T.	10	10	40	1.5	21	2050	.....	.....
$\frac{1}{10}$ A. T.	10	10	80	1.5	30	1968.6	.....	.....
$\frac{1}{10}$ A. T.	10	10	80	1.5	22	1944.6	135.2	35.0
$\frac{1}{10}$ A. T.	10	10	80	1.5	21	1984.8	70.2	34.6
$\frac{1}{10}$ A. T.	10	10	80	1.5	21	1914.8	.....	.....

Ore No. 2,708-1 consisted of smaltite, native bismuth and native silver in calcite; R. P. = 5; Ni, 0.8; Co, 8; and As, 55 per cent. The scorification-assay gave 404.8 oz. and the combination wet-and-dry analysis gave 403.7 oz. of silver per ton.



Crucible-Method.						
Ore.	Sodium Bicarbonate.	Borax-glass.	Litharge.	Argols.	Silver in Lead.	Silver in Slag.
$\frac{1}{10}$ A. T.	g. 10	g. 6	g. 35	g. 1.5	Oz. per Ton. 402.6	Oz. per Ton. Not assayed.
$\frac{1}{10}$ A. T.	10	6	80	1.5	388	Not assayed.
$\frac{1}{10}$ A. T.	10	6	100	1.5	392	11.8

The same ore after amalgamation gave, by the scorification-assay, 292 and 291.2 oz., while by the combination wet-and-dry analysis the result was 292.2 oz. of silver per ton.

Crucible-assays.						
Ore.	Sodium Bicarbonate.	Borax-glass.	Litharge.	Argols.	Lead Button.	Silver.
$\frac{1}{10}$ A. T.	g. 10	g. 6	g. 35	g. 1.5	g. 24	Oz. per Ton. 293
$\frac{1}{10}$ A. T.	20	6	35	1.5	23	292.8
$\frac{1}{10}$ A. T.	20	6	35	1.5	25	291.8
$\frac{1}{10}$ A. T.	10	6	60	1.5	24	288
$\frac{1}{10}$ A. T.	10	6	80	1.5	26	283.6
$\frac{1}{10}$ A. T.	10	6	100	1.5	26	279.8

I have a number of other examples, but these should be sufficient to illustrate the fact to which I wish to call attention. The ores used carried practically no gold.

The same lot of litharge was used in all the fusions, and the conditions under which the fusions were conducted were as nearly identical as possible. Heavy crystals of litharge were found on all the cupels.

Only  $\frac{1}{10}$  A. T. of ore was used in the assays, because Messrs. Frame and Jaccard found that in case of ore No. 2,687-2, carrying 12.92 per cent. of nickel, if 5 g. of ore were taken and 35 g. of litharge were used, the resulting lead button would not cupel. If 5 g. of ore were taken and the litharge increased to 80 g., in order to slag the nickel, the button would cupel but the silver-results were low.

Some ores from the Cobalt district carry so large a percent-

age of nickel that  $\frac{1}{10}$  A. T. of ore is the limit that can be used in either scorification- or crucible-work, and low litharge is inapplicable in the latter method. The following ore serves as an illustration: Ore No. 2,708-2, niccolite (NiAs); R. P. = 5.3; Ni, 38.01; Co, 1.19; and As, 53.31 per cent.

Ore.	Sodium Bi-carbonate.	Borax-glass.	Litharge.	SiO <sub>2</sub> .	Argols.	Ratio of Litharge to Ni in Ore.	Lead.
$\frac{1}{10}$ A. T.	g. 15	g. 10	g. 120	g. 5	g. 1	214 to 1	24
$\frac{1}{10}$ A. T.	15	10	120	5	None.	107 to 1	25
$\frac{1}{10}$ A. T.	15	10	120	5	Nitre-1	54 to 1	25

The lead buttons from  $\frac{1}{10}$  and  $\frac{2}{10}$  A. T. of ore would not cupel, both cupels being covered with a thick film of green nickel oxide (NiO).

The lead button from  $\frac{1}{20}$  A. T. of ore would just cupel, leaving the cupel stained green.

One of the advantages of the crucible-method is that it enables the assayer to use a larger amount of ore than in the scorification-method, but from the foregoing data there seems to be no advantage in this method over scorification on ores carrying much more than 10 per cent. of nickel. When, however, the ores, either siliceous or calcareous, are poor in silver and carry only a small percentage of nickel or similar impurity, the crucible-method, with low litharge, can be used to advantage.

Cobalt is much more readily slagged than nickel, especially in the presence of alkali and silica, and does not so readily pass into the lead button, therefore ores quite rich in cobalt can be assayed by the crucible-method, a considerable amount of ore be used and the litharge kept low.

From 80 to 90 per cent. of the cobalt, if a reasonable amount of ore is used, will pass into the slag in either scorification- or crucible-work.

It is a question with me as to the cause, in certain cases, of the uneven and low results in silver when high litharge is used in the crucible-assay, but apparently the silver passes in some way into the slag. At first I thought that, in the examples given, either the arsenic, the nickel or the combination of both was the cause, but this was not true of all ores. Some ores

carrying considerable nickel, cobalt and arsenic gave good results as well as an ore carrying Co, 0.67; Ni, 0.44; and As, 0.6 per cent. in a gangue consisting of silica and calcite.

The question of high or low temperature does not seem to influence the slagging of the silver unless this takes place at some particular period of the fusion. Owing to this uncertainty as to the action of the litharge, I prefer the scorification-method for ores from the Cobalt district which carry much nickel, using  $\frac{1}{20}$  or  $\frac{1}{10}$  A. T. of ore, from 3 to 8 g. of borax-glass, high lead (65 g. or more), with some silica and a medium high temperature. If obliged to use the crucible-method, I keep the litharge low and take such an amount of ore that both high litharge and nitre are avoided.

If all ores from this district are ground very fine, thus removing the greater part of the silver pellets, it is surprising how uniform are the results obtained by the scorification-method—something that I have not found by the crucible-method nor in some ores when using 0.5 A. T. for the combination wet-and-dry analysis.

It is hoped that this paper will bring out the experiences of some other assayers.

## **Zinc Oxide in Iron-Ores, and the Effect of Zinc in the Iron Blast-Furnace.**

BY JOHN J. PORTER, CINCINNATI, OHIO.\*

(Toronto Meeting, July, 1907.)

UNUSUAL problems have arisen at certain iron blast-furnaces in Virginia through the fact that the ore-supplies, derived from the Oriskany formation, contain from a trace up to 1 per cent. of zinc oxide. Since the technical literature bearing on this subject is very scant, the following notes, based on personal experience, will probably be of value to those of our members who are interested in iron blast-furnace practice.

The course of zinc through the blast-furnace is readily traced. Entering the throat as zinc oxide, finely disseminated through the ore, it descends unchanged to the fusion-zone, since a temperature of 1,000° C. or more is required for its reduction. At the fusion-zone, the zinc oxide is reduced by solid carbon to metallic zinc, which is set free as vapor and rises with the ascending gases to the cooler zones of the furnace. In cooling through the range of temperature from 1,000° to 500° C. the zinc is re-oxidized according to the reaction  $\text{Zn} + \text{CO}_2 = \text{ZnO} + \text{CO}$ , and the resulting zinc oxide, being in a very fine state of division, is readily carried along by the ascending gases. Portions, however, deposit on the descending stock and are carried down, again to pass through the same cycle of changes. Still other portions deposit on the lining of the stack, and gradually form hard masses of "cadmia." Of the remainder of the zinc oxide, the greater part passes out of the furnace, and is either deposited in the down-comer, dust-trap, stoves, boilers and flues, or passes through the chimney into the atmosphere. A small portion escapes reduction and enters the slag as zinc oxide, while still another portion is absorbed into the lining of the furnace.

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Although a quantitative estimate of the final distribution of the zinc oxide charged into a furnace is attended with much difficulty and uncertainty, the following approximate results, covering a period of six months at one plant, may be of interest. The figures are percentages of the total zinc oxide charged into the furnace during the period, as determined from the weight of ore used, and the average percentage of zinc contained therein :

	Per Cent.
In furnace-cadmia (weighed), . . . . .	8
In down-comer deposits (weighed), . . . . .	9
In flue-cadmia (weighed), . . . . .	13
In flue-dust (estimated), . . . . .	9
In dust-catcher dust (estimated), . . . . .	8
Absorbed in hearth- and bosh-lining (weighed), . . . . .	4
Absorbed in inwall-lining (estimated), . . . . .	5
Eliminated in slag (calculated), . . . . .	12
Lost at furnace-top through the lowering of bell (calculated), . .	9
Unaccounted for and error, in stoves, boilers, chimney-flues, and lost through draft-stack (difference), . . . . .	23

The difficulties which arise from the presence of zinc in the blast-furnace may be divided into three classes, according to the causes :

(1) Mechanical action ; (2) physical action ; and (3) chemical action.

1. *Mechanical Action*.—Under this head are such troubles as the choking of the stove-checkers and gas-flues by the zinc oxide dust, and the obstruction of the down-comer and furnace-throat by cadmia formations. These formations are of considerable interest, and have been noted in technical literature.<sup>1</sup> They form a ring adhering to the lining just below the point where the stock strikes in charging, which frequently attains sufficient thickness to obstruct seriously the passage of the stock and gases. In furnaces having a single point of take-off for the gases the tendency is for the cadmia to deposit chiefly on the side opposite this point, which destroys the symmetry of the stock-line and causes an uneven distribution of the stock, with all its attendant evils.

<sup>1</sup> Taylor, A Blast Furnace Problem with Zinc, *Engineering and Mining Journal*, vol. lxvii., p. 469 (1899) ; Means, The Flue-Dust of the Furnaces at Low Moor, Va., *Trans.*, xvii., 129 to 131 (1888-89) ; Firmstone, Note on a Deposit of Cadmia in a Coke-Furnace, *Trans.*, vii., 93 to 99 (1878-79).

The cadmia has a stratified structure, is greenish gray in color, is exceedingly hard, heavy and tough, and closely resembles the mineral zincite in all physical properties. It usually contains from 85 to 90 per cent. of  $\text{ZnO}$ , and from 0.5 to 1 per cent. of metallic zinc.

In the early days of the iron industry of Virginia, these cadmia deposits were not recognized as having any value, and large quantities were thrown on the dumps. The application of chemistry to blast-furnace practice, however, caused the value of the cadmia to be recognized, and now it is considered an asset of sufficient importance, when recovered, to offset largely the difficulties attending its presence in the furnace.

The prevention of the difficulties due to mechanical action is quite simple, and for the most part very effective. Two-pass stoves, with wide checkers and overhead flues, practically eliminate any troublesome clogging. A down-comer of ample size and proper inclination will usually remain free from obstructions during an average blast, while if an obstruction should form, a stop of a few hours will suffice to cut out the cadmia at the throat, where it deposits the thickest.

The removal of the cadmia formed in the furnace itself is more difficult. The old-time remedy was to blow out the furnace every six months and remove the deposits. A variation practiced by some adventurous furnace-men was to bank the furnace and cut out the cadmia from a swinging scaffold, but in this case it is needless to say that the work was not accomplished without the "gassing" of every one employed on the job.

In recent practice encouraging results have been obtained by the use of cast-iron stock-linings. The zinc oxide apparently does not adhere to the iron with any considerable tenacity, and any thin coating that forms is cracked off, leaving the plates clean. Water-cooled plates also have been tried, but they are no more effective than the plain ones, while they are quite liable to crack and allow the water to leak into the stack and backing. In one case this leakage caused a serious scaffold, the cause of which remained unsuspected for some time.

One result of the cast-iron stock-lining, which was not anticipated, was the formation of a cadmia-deposit on the brick lining lower in the furnace. It had been thought that the wear

of the stock would prevent any accumulation there, but in one instance which came to my notice a zinc ring, about 1 ft. thick and 3 ft. wide, was found at this point after a blast of nine months. The deposit, however, was much smaller than would have formed if the iron plates had been omitted; moreover, its thickness was nearly uniform, so that there was but little effect on the distribution of the stock.

2. *Physical Action.*—Under this head are included the disturbances due to the absorption of heat by masses of zinc oxide which reach the hearth. These masses may come either from a cadmia-deposit at the stock-line, or from a scaffold or other accumulation lower in the furnace. In explanation of this latter assertion it should be said that zinc oxide possesses the power of entering into these accumulations to an almost incredible extent, and greatly augments the difficulties due to them. It is not generally so recognized, but I believe that zinc oxide not only enters into the scaffold after its formation, but also very greatly increases the tendency to form these accretions; my opinion being based largely on the great tenacity with which zinc oxide adheres to the lining.

In an earlier article on this subject,<sup>2</sup> I took the ground that a "zinc-slip," or fall of zincy material to the hearth, would have no material effect on the working of the furnace, my opinion being based on calculations of the theoretical heat-absorption caused by the fall of one ton of cadmia-deposit. Later experiences have caused me to modify this view to some extent. It is probably true that a fall of cadmia-deposit coming at a time when the furnace is hot will cause only a slight chilling, and will not, as a rule, affect the grade of the iron. The fall of a scaffold or scab containing a large proportion of zinc, however, is a more serious matter, since the heat demanded for the reduction and volatilization of the zinc is taken from the hearth of the furnace at the time when it can least be spared.

After a heavy slip of this character the cinder comes up black and glassy, fumes strongly of zinc oxide, and shows little blue flames of burning zinc as it runs down the gutter. The gas at the top of the furnace when the bell is lowered burns with a white flame and gives off dense yellow fumes of zinc

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<sup>2</sup> *Iron Age*, Mar. 24, 1904, p. 10.

oxide. At some of the older furnaces, having badly-cracked crucible-jackets, it is not uncommon to find metallic zinc oozing out of the cracks at such times.<sup>3</sup> The change in the condition of the furnace takes place very suddenly; and, as a rule, the greater portion of the zinc is eliminated from the hearth within 8 or 4 hr. There is usually a second less-marked appearance of zinc in the hearth about 10 or 12 hr. after the first one, and occasionally a third after still another interval. These I attribute to the deposition of a portion of the zinc as oxide upon the stock at a certain zone in the furnace, whereby it is returned to the hearth. I have never been able to detect zinc in the cast-iron made during these periods, and it only enters the slag to the extent of a few hundredths of 1 per cent., or but slightly in excess of the normal amount. This seems rather remarkable, and I am at a loss to explain it satisfactorily.

The cooling-effect exerted by the zinc oxide in the hearth of the furnace is made up as follows: heat necessary to raise the temperature of the zinc oxide from, say, 800° C. to 1,300° C.; heat absorbed by the reduction of zinc oxide by carbon; latent heat of fusion of the resulting zinc, and latent heat of evaporation of the zinc. (Since the subsequent condensation and re-oxidation of the zinc take place in the higher zones of the furnace, the heat developed is not available in the hearth and need not be considered here.) Based on a quantity of 1 lb. of zinc oxide, the loss of heat in pound-calories in the items just enumerated is:

	Calories.
Sensible heat absorbed, $0.15 \times 500$ , . . . . .	75
Heat of reduction, $1051 - 356$ , . . . . .	695
Latent heat of fusion, . . . . .	22.5
Latent heat of evaporation (approximately), . . . . .	425
Total, . . . . .	1,217.5

Assuming that 1 lb. of coke in the blast-furnace develops 3,800 calories, it is evident that 0.32 lb. of coke will be necessary to furnish the 1,217.5 calories, while an additional 0.148 lb. of carbon, or, say, 0.165 lb. of coke, is consumed in the reduction reaction, making a total of 0.485 lb. of coke for 1 lb. of zinc oxide.

<sup>3</sup> See, also, Firmstone, Note on a Deposit of Cadmia in a Coke-Furnace, *Trans.*, vii., 93 to 99 (1878-79).



In order to prevent any possible misunderstanding, it should be noted that, while these figures refer to the heat lost to the hearth of the furnace, the calculations given in my former paper, previously referred to, deal only with the heat lost to the furnace as a whole. This is the chief cause of the considerable difference in the two results.

The only method which has been developed to correct this disturbance is the crude one of charging extra fuel upon the first indications of a "zinc-slip." Probably in this case "an ounce of prevention is worth a pound of cure," and extreme care to prevent the formation of scaffolds would be of more benefit than anything else. It is unfortunate, therefore, that the poor blowing-equipment and the absence of proper stocking-facilities at many of the plants in Virginia cause them to run irregularly, and render them particularly liable to this form of trouble.

3. *Chemical Action.*—Under this head may be discussed the action of zinc oxide on the fire-brick lining of the furnace. It is unusual for a furnace in this district to run more than a year without relining the hearth and bosh, and although not generally so recognized, I believe that the presence of zinc oxide is the chief cause of this deterioration. An examination of the lining remaining in these furnaces after blowing-out reveals the following facts: The bricks in the hearth and lower part of the bosh are very soft and of a greenish-black color. They contain considerable carbon, and 40 per cent. or more of zinc oxide, while small yellow crystals of the zinc oxide are abundant. Higher up in the furnace the bricks are firmer, and contain less zinc oxide and carbon, while above the mantle the structure is unchanged, but the color is deep blue. Analysis shows only a trace of carbon, with about 20 per cent. of zinc oxide. The blue color is commonly attributed to zinc by the furnace-men of the district, but as I have noticed it in other furnaces not using zincy ores, I am disposed to attribute it to the presence of titanium in the brick. The researches of Dr. Seger have shown that titanitic acid gives a blue color to kaolin when heated to a high temperature, and it is well known that many, if not most, of our fire-clays contain appreciable amounts of this element.

Dr. Steger, in an investigation of the cause of the disintegra-

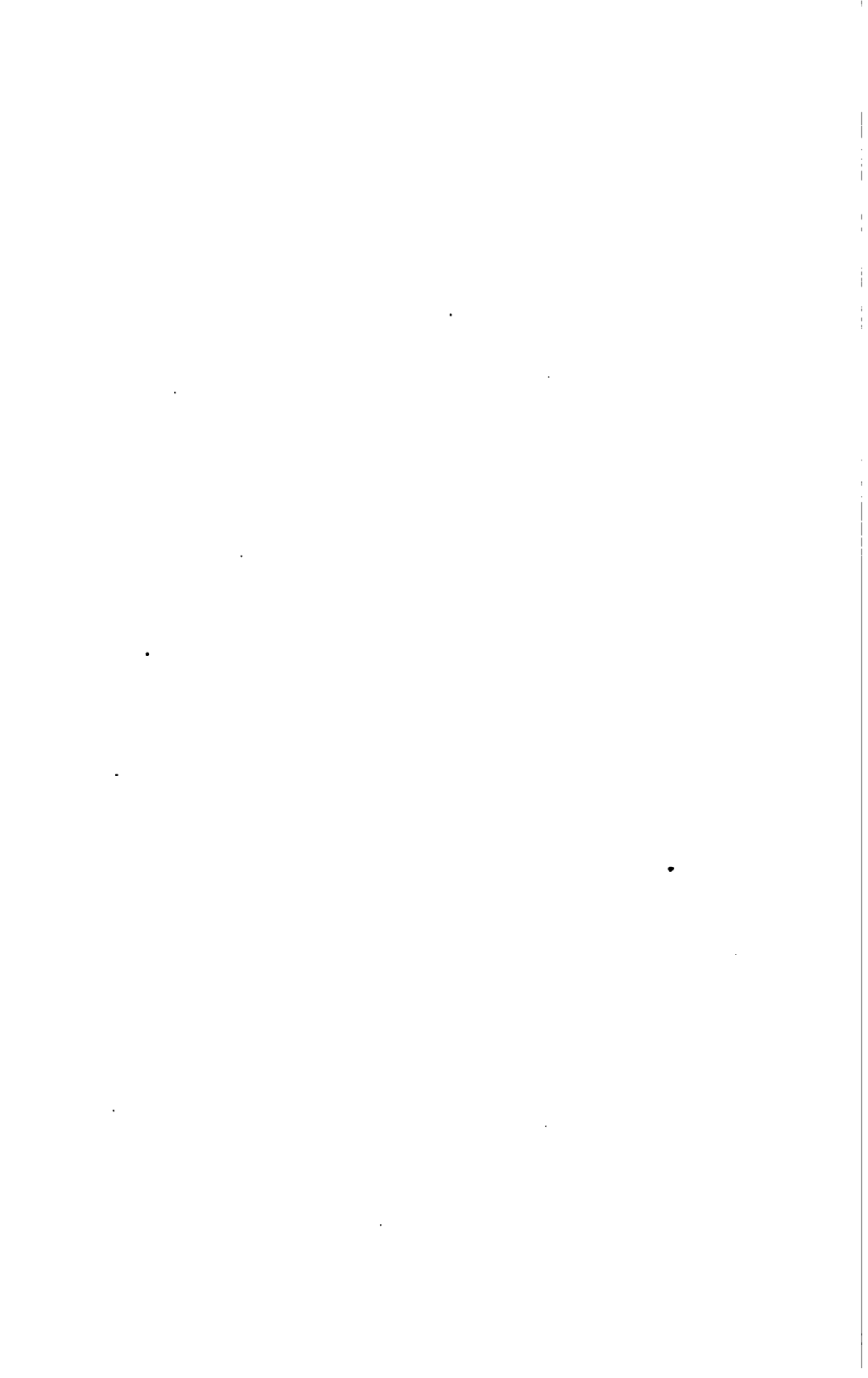
tion of zinc-muffles,<sup>4</sup> found that the zinc-vapors attack the clay substance according to the reaction  $\text{Al}_2\text{O}_3, 2\text{SiO}_2 + \text{Zn} + \text{CO}_2 = \text{Al}_2\text{O}_3, \text{ZnO} + \text{CO} + 2\text{SiO}_2$ , forming zinc-spinel and tridymite. Willemite ( $2\text{ZnO}, \text{SiO}_2$ ) is also formed. Dr. Muehlhauser finds that the formation of zinc-spinel takes place principally when the muffle is still new and porous. The absence of a glaze on the side next to the fuel allows the gases to diffuse into the walls of the muffle, where, meeting the zinc-vapors, the reaction takes place.

The work of Dr. Steger and Dr. Muehlhauser affords a very clear explanation of the action of zinc on the iron blast-furnace lining, although it does not account for the presence of finely-divided carbon or of free zinc oxide. This latter, however, probably results from the fact that the lining is considerably cooler than the hearth-space, permitting the oxidation of zinc by carbon dioxide. It is assumed that zinc-spinel forms at temperatures above the reduction-point of zinc oxide, which is more than  $1,000^\circ \text{C.}$ , and, this being true, the clay would be attacked on the interior surface of the lining with a formation of zinc-spinel, while farther out, where cooler from radiation, there would be deposition of zinc oxide without disintegration of the brick. It is actually found that the bricks on the inner surface of the furnace are badly disintegrated, have lost all trace of the original structure, and are so soft that they can be crumbled between thumb and finger while farther back the structure of the brick begins to show; it is harder, and the yellow crystals of zinc oxide are abundant. These observations show that theory and fact are in close agreement.

So far as I am aware, no experiments have been tried with the object of reducing the action of the zinc on the lining of the iron blast-furnace. It is improbable that anything could be done with a glaze, since the wear of the lining is comparatively rapid. A series of experiments to show the relative resistance of the various brands of fire-bricks to the action of zinc-vapors would undoubtedly lead to beneficial results, and, in view of the possibility of lengthening the life of the lining, and thereby securing a longer campaign for the furnace, it seems well worth while to undertake the experiments suggested.

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<sup>4</sup> *Tomindustrie Zeitung*, abstracted in the *Transactions of the American Ceramic Society*, vol. vii., p. 277 (1905).



## Chlorination of Gold-Ores; Laboratory-Tests.

BY A. L. SWEETSER, CANANEA, SONORA, MEXICO.

(New York Meeting, April, 1907.)

### I. INTRODUCTION.

EXPERIENCE has shown how difficult it is to obtain information regarding laboratory-tests in connection with the chlorination-process for the extraction of gold from its ores, and I therefore present the following method, somewhat in detail, for the benefit of those who may desire to pursue research work in this field.

The ore chosen was a partly-decomposed porphyry, extremely siliceous and comparatively soft, and of an average value per ton of from \$25 to \$26 in gold and \$0.68 in silver. The chemical analysis gave:  $\text{Fe}_2\text{O}_3$ , 3.35;  $\text{FeS}$ , 1.5;  $\text{MnO}_2$ , 0.75;  $\text{ZnCO}_3$ , 4;  $\text{Al}_2\text{O}_3$ , 3.20;  $\text{H}_2\text{O}$ , 0.7;  $\text{SiO}_2$ , and insol., 83.50 per cent.

The ore, first crushed to pass a 5-mesh screen, was coned and quartered until a 45-lb. sample was obtained. Samples for assay and analysis, taken from this lot by means of riffles, were crushed to pass a 100-mesh screen. The original sample was divided into 10-lb. lots, of which one was crushed to pass a 10-mesh screen; another through a 12-; the third through a 20-, and the last through a 30-mesh screen.

Because of the production of an excessive quantity of fine material it was deemed inexpedient to crush finer than 30-mesh size—a decision the wisdom of which is proved by the data in Table I., showing the increasing ratio of slimes, in proportion as the ore is crushed finer.

In order to determine the percentage of fines in the sizes of mesh selected, a weighed sample of ore was taken from each mesh, and a sample from the 10-mesh lot was passed successively through 20-, 40- and 100-mesh screens, and the percentage remaining on each screen determined. This process was repeated with the 12-, 20- and 30-mesh lots, with the results given in Table I.

TABLE I.—*Screen-Analysis of Crushed Sample.*

Size of Mesh.	Held on 20.	Held on 40.	Held on 100.	Passed 100.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
10	63	13	11	13
12	45	23	16	16
20	.....	53	24	23
30	.....	32	33	35

## II. ROASTING.

When the analysis was complete, some of the ore was chlorinated in a manner to be explained later, and it was found that no practically important extraction could be obtained, due to the fact that the sulphur absorbed a large part of the chlorine and that the gold was not in a suitable form to be attacked by chlorine. In order to reduce the sulphur to a working-limit (about 0.2 per cent.), it was necessary to roast.

For preliminary roasting, a small amount of ore in scorifiers was put in a muffle and the heat gradually raised, the total time of roasting being 2, 3 and 4 hr. Table II. shows that the ore was roasted within the 0.2 per cent. limit of sulphur at the end of 3 hr., and dead roasted at the end of 4 hr.

TABLE II.—*Elimination of Sulphur by Roasting.*

Size of Mesh.	2 Hr.	3 Hr.	4 Hr.
	Per Cent.	Per Cent.	
10	0.13	0.08	trace
12	0.24	0.18	trace
20	0.31	0.17	trace
30	0.26	0.19	trace

The 3-hr. roast was taken as the one on which to work, and in roasting the ore for the chlorination-tests, roasting-dishes were placed in a muffle, the door of which was kept open, the heat being gradually raised to redness; the endeavor being to maintain as great a heat as possible without sintering the ore. A number of results obtained from the 3-hr. roasts were not altogether satisfactory, and the time of roasting was lengthened to 4 hr., which practically corresponds to a dead roast.

## III. CHLORINATION.

The chlorination proper was carried out in the following manner in soda-water bottles: The chloride of lime was first

weighed and charged. Then the 100 g. of ore was introduced, and water in sufficient quantity to give the ore the consistency of mud. Finally, the sulphuric acid was charged and the bottle sealed by pulling the patent stopper in place, inserting a wooden wedge to tighten it, and filling the neck with melted paraffine. It was necessary to conduct this operation with care and rapidity, and to avoid all agitation, because the chlorine soon began to bubble up through the paraffine if the latter did not solidify immediately. It is advisable to have the bottles perfectly dry before charging the chloride of lime, so as to avoid the premature generation of chlorine.

The bottles were placed in an agitator, and rotated for the required time. This agitator consists essentially of a circular disk 2 in. in thickness and 12 in. in diameter. The bottles were secured by rubber bands in six semicircular notches around the periphery. The disk lies in a plane inclined to its axis of rotation at an angle of  $80^\circ$ , and is connected by belt to a  $\frac{1}{10}$ -h.p. motor, which furnished ample power; 30 rev. per min. was the average speed at which the tests were made.

In the first series of experiments, on unroasted ore, with 2 g. of chloride of lime and 4 g. of sulphuric acid, the samples were agitated for 1 and 2 hr. by hand. In the second and all subsequent tests the agitator was used. The second series was on ore roasted for 3 hr., with 2 g. of chloride of lime and 4 g. of sulphuric acid, the agitation lasting 1, 2, 3, 4 and 5 hr., respectively. These gave results which, though a great improvement over those on unroasted ore, were not entirely satisfactory.

#### IV. LEACHING.

In each case, as soon as the time of chlorination was complete, the bottles were opened and the excess chlorine allowed to escape; then the ore was leached or filtered in sand-filters constructed as follows: A common acid-bottle, upside down, with the bottom removed and a stopper with a pinch-cock inserted in the neck, formed the percolator. Pure quartz was crushed and screened to pass 10-, 20- and 30-mesh screens, respectively. A few pebbles larger than 10-mesh size were placed in the bottom, above which was a layer 1 in. thick of quartz of 10-mesh size, then 0.75 in. of 20-mesh, and lastly 0.5 in. of 30-mesh size, and above the uppermost layer was placed a cloth, to

catch the ore, and thus preserve the tailings. Too much fine sand prolonged the term of filtration excessively, while too much coarse material allowed the fines of the ore to pass through the filter. It was found impossible to recover all the fines in the tailings for assay-purposes, since a portion passed through the cloth. In some cases a portion of the fines was caught in the sand, while in others the fines passed into the filtrate. It was found that to remove all traces of gold chloride from the tailings each 100-g. charge required about 700 cc. of wash-water, which is equivalent to about 14,000 lb. of water per ton of ore. In practice this amount of water would be considered excessive, and would increase the number of settling-tanks and precipitating-vats to such an extent as to increase seriously the working-cost. The small sand percolator acts like the paper filter used in chemical work, the water being drawn through the cloth along the glass, without coming in contact with the ore, while in the barrel the water must pass through the whole body of ore before reaching the filter. In the mill a further economy of wash-water is often effected by using the last washing of one barrel for the first washing of the next barrel. The washing is considered complete when, on passing hydrogen sulphide through the wash-water, no gold sulphide is precipitated.

#### V. TREATMENT OF TAILINGS.

As soon as the leaching is complete, the cloth containing the tailings is removed and the tailings dried, bucked to pass an 80-mesh sieve and assayed. The difference from the original assay is the amount extracted by the chlorine, and may be calculated in terms of per cent. as follows:

Gold before treatment, . . . . .	1.27 oz. per ton.
Gold after treatment, . . . . .	0.96 oz. per ton.
	<hr/>
	0.31

$$1.27 : 100 :: 0.31 : x = 24.2 \text{ per cent., etc.}$$

The actual extraction was slightly higher than that indicated by the results obtained in the experiments on account of the inaccuracy of the tailings-assay, which arose from the passage of some of the fines (obviously thoroughly leached) through the cloth, thus giving a higher result for the tailings-assay.

TABLE III.—*Extraction by Chlorinating Unroasted Ore of a Gold-Value of \$26.25 Per Ton.*

Size of Mesh.	Time of Chlorination.	Tailings-Assay.	Value of Tailings-Assay.	Percentage of Extraction.
	Hours.	Ounces.		
10	1	0.96	\$19.30	24.2
12	1	1.2	24.89	4.8
20	1	1.23	25.42	3.15
30	1	1.27	26.25	0
10	2	0.98	19.60	24.88
12	2	1.27	26.25	0
20	2	1.27	26.25	0
30	2	1.27	26.25	0

NOTE.—2 g. of bleach and 4 g. of sulphuric acid were used.

TABLE IV.—*Extraction by Chlorinating Ore Roasted 3 Hours. (Value of Original Ore was \$26.25 Gold Per Ton.)*

Size of Mesh.	Time of Chlorination.	Tailings-Assay.	Value of Tailings-Assay.	Percentage of Extraction.
	Hours.	Ounces.		
10	1	0.13	\$2.69	89.75
12	1	0.10	2.07	92.11
10	2	0.20	4.13	84.26
12	2	0.19	3.92	84.06
20	2	0.12	2.48	90.55
30	2	0.12	2.48	90.55
10	3	0.18	3.72	85.82
12	3	0.08	1.66	93.67
20	3	0.16	3.30	87.42
30	3	0.2	4.13	84.26
10	4	0.15	3.10	88.20
12	4	0.1	2.07	92.1
20	4	0.16	3.30	87.42
30	4	0.23	4.75	81.94
10	5	0.96	19.83	24.4
12	5	0.4	8.26	68.52
20	5	0.36	7.18	71.65
30	5	0.32	6.10	76.76

NOTE.—2 g. of bleach and 4 g. of sulphuric acid were used.



TABLE V.—*Extraction by Chlorinating Ore Roasted 4 Hours.*  
(Value of Original Ore was \$26.25 Gold Per Ton.)

Size of Mesh.	Time of Chlorination.	Tailings-Assay.	Value of Tailings-Assay.	Percentage of Extraction.
	Hours.	Ounces.		
10	1	0.66	\$13.64	53
12	1	0.36	7.44	72
20	1	0.05	1.03	96.1
30	1	0.14	3.70	88.9
10	2	0.21	4.34	84.8
12	2	0.11	2.27	91.3
20	2	0.03	0.62	97.6
30	2	0.06	1.24	95.3
10	3	0.45	9.30	64.3
12	3	0.14	3.70	88.2
20	3	0.1	2.07	92.1
30	3	0.08	1.65	92.9
10	4	0.17	3.51	86.6
12	4	0.28	5.78	77.8
20	4	0.02	0.41	98.4
30	4	0.04	0.82	96.1
10	5	0.18	3.70	86
12	5	0.24	4.96	81.2
20	5	0.07	1.44	94.5
30	5	0.06	1.24	94.9

NOTE.—3 g. of bleach and 6 g. of sulphuric acid were used.

## VI. DISCUSSION OF TESTS.

The results of the experiments on ore roasted for 3 hr. were unsatisfactory, since the best extraction was only 93.67 per cent. Assuming that the poor extraction was due to the 0.2 per cent. of sulphur left in the ore, experiments were then made on ore that had been roasted 4 hr., which entirely eliminated the sulphur. At the same time the quantity of bleaching powder was increased from 2 to 3 g., and the quantity of sulphuric acid from 4 to 6 g. Under these conditions the results were entirely satisfactory, the best extraction being 98.4 per cent. The percentage of extraction varied with both the size of the ore and the time of chlorination. The former showed an average extraction as follows: 10-mesh size, 72.84 per cent.; 12-mesh, 82.1 per cent.; 20-mesh, 95.7 per cent.; and 30-mesh, 93.6 per cent. With regard to the time of the experiment, the average extraction was: 1 hr., 77.5 per cent.; 2 hr., 92.125 per cent.; 3 hr., 84.37 per cent.; 4 hr., 89.7 per cent.; and 5 hr., 89.15 per cent. The best single test was with 20-mesh size and 4 hr. chlorination, using 3 g. of bleach and 6 g. of sulphuric acid. Accordingly, this size and time were adopted, leaving only the quantity of bleach and of acid to be determined.

## VII. TESTS FOR QUANTITY OF BLEACH AND OF SULPHURIC ACID.

Using ore of 20-mesh size and chlorinating for 4 hr. the results obtained by varying the quantity of sulphuric acid and of bleach are given in Table VI.

TABLE VI.—*Results Obtained by Varying the Quantity of Bleach and of Acid.*

No. of Test.	Quantity of Bleach.	Quantity of Sulphuric Acid.	Tailings-Assay.	Percentage of Extraction.
	Grams.	Grams.	Oz. Per Ton.	
1	0.5	1	0.05	96.1
2	1.0	2	0.055	95.7
3	1.5	3	0.03	97.6
4	2.0	4	0.15	88.2
5	2.5	5	0.04	96.9
6	3.0	6	0.02	98.4
7	3.5	7	0.025	98.1

The results given in Table VI. show that the first, third and sixth tests are the only ones worthy of consideration. Test No. 1 required 10 lb. of bleach and 20 lb. of sulphuric acid per ton of ore. The cost of 10 lb. of bleach at 1 c. is \$0.10, and of 20 lb. of sulphuric acid at 0.6 c. is \$0.12, giving a total cost of \$0.22. Test No. 3 required 30 lb. of bleach and 60 lb. of acid, which cost \$0.66. No. 6 required 60 lb., and 120 lb., costing \$1.32. The value of the gold extracted in Test No. 1 was:  $\$26.25 \times 0.961 = \$25.22$ ; No. 3,  $\$26.25 \times 0.976 = \$25.62$ , and No. 6,  $\$26.25 \times 0.984 = \$25.83$ .

Balancing the increased extraction of gold against the increased cost of chemicals, Test No. 1 was the most economical. In the barrel-test based on Nos. 1 and 3 the latter proved to be the better. The most satisfactory results of these tests show that the ore should be 20-mesh size, the time of the roast 4 hr., the quantity of bleach 30 lb., and the quantity of acid 60 lb. per ton of ore treated.

## VIII. TREATMENT OF THE GOLD CHLORIDE SOLUTION.

The gold chloride solution was treated with hydrogen sulphide, which precipitated the gold as gold sulphide, the solution being constantly stirred during the operation in order to facilitate settling. After complete precipitation the solution was allowed to settle for a few hours, and the clear supernatant

liquid was decanted through a filter; finally, the gold sulphide was washed on this filter, dried, and roasted until all traces of sulphur had disappeared.

The gold was refined in scorifiers with test-lead, borax, and silica, the lead button thus obtained cupelled, and the gold weighed. From this weight the percentage of extraction may be determined as a check on the results obtained by the tailings-assay. This method, however, seems of little practical value because of the intricacy of the manipulation required, and the liability of loss of gold in the roasting, and in the burning of the filter-paper on which it is caught.

### IX. BARREL-TEST.

In order to approximate more nearly to conditions of actual practice, a chlorination-test was made in a small barrel of 100-lb. capacity, basing the experiment on the data obtained from the laboratory experiments.

An iron barrel 2 ft. long and 1.25 ft. in diameter, inside measurements, lined throughout with lead, and provided with the conventional man-hole and inlet- and outlet-valves, was used. An internal wooden frame-work was provided to support the asbestos filter.

A charge of ore, weighing 72 lb., was crushed to 20-mesh size, and roasted for 4 hr. on the floors of a series of muffles. The barrel, having the filter in place, was filled one-third full with water, to which 2.1 lb. (3 per cent. of the weight of the ore) of sulphuric acid was added. The ore was then introduced, followed by 1.05 lb. of bleach (1.5 per cent. of the weight of the ore). The man-hole and valves were quickly and securely closed, and the barrel was rotated for 4 hr. At the end of this time the rotation was stopped, with the filter underneath; the valves were opened and the leaching began. Atmospheric pressure being insufficient to cause rapid filtering, on account of the fines which formed a cement-like cake over the top, compressed air was used to facilitate the leaching. When the leaching was complete, the barrel was closed, rotated a few times, and then opened and emptied. The tailings-sample was taken, when the leaching was finished, by means of a short iron pipe, which was plunged into the ore at different places. Three check-assays gave an average of 0.083 oz. of gold per ton (or \$1.74), which shows an extraction of 93.46 per cent.

During the leaching, 50 gal. of wash-water was used, which is equivalent to 1,388 gal. per ton of ore. This large excess was due to the care taken to remove the last traces of gold chloride from the ore.

These experiments, both laboratory and barrel, demonstrate the suitability of the ore for treatment by chlorination. The original ore assayed \$26.25 in gold and \$0.68 in silver per ton. Assuming the extraction obtained in the barrel-test to be 93.46 per cent., there was a loss of value of \$1.74 in gold, and all of the silver, making a total loss equal to \$2.42 per ton.

The smelter-charge for an ore of this character is about \$10 per ton, and neglecting the cost of eliminating the sulphur (which in general is in favor of the chlorination-process), there is a gain in chlorination above smelter-charge of \$10, less \$2.36, equal to \$7.64 per ton.

Ores of the character mentioned above can be chlorinated at a cost of from \$2 to \$5 per ton, which gives a substantial gain over the cost of treatment in a custom-smelter.



## **Physical Factors in the Metallurgical Reduction of Zinc Oxide.**

BY WOOLSEY MCA. JOHNSON, NEW YORK, N. Y.

(Toronto Meeting, July, 1907.)

INDEPENDENTLY of the recognized chemical reactions involved in the production of metallic zinc, the process is affected by physical conditions in efficiency, and by commercial as well as technical economy. To offer some observations concerning these conditions is the purpose of the present paper.

Among the important elements of this problem is the physical nature of the particles constituting the mass of zinc oxide to be reduced. This may be the result, either of the manner of the original deposition of the mineral, or of the treatment to which it has been subjected in the roasting-furnace. The physical character of the reducing-agent is another important factor, since the carbon of some coals is much more active in reduction than that of others. The degree of fineness, whether of ore or coal, or both, likewise plays a significant part. These factors, together with the physical admixture of foreign substances with the ore, may give rise also to chemical "side-reactions," sometimes hindering or retarding, and sometimes accelerating, the reduction. Finally, thermal conditions, including the relative conductivity of the materials, deserve to be taken into account.

In firing a furnace with retorts charged with a mixture of roasted ore and coal, the first reaction is naturally the boiling-off of the contained water; the next is the distillation of the light hydrocarbons from the coal; the next is the reduction of the iron oxide to protoxide and sub-oxide successively, and then to metallic sponge; and the final reaction is the reduction of the zinc oxide in the ore by the carbon to metallic zinc. This reaction commences at 1,022° to 1,060° C., according to the physical nature and condition of the coal and ore.

Since the retort and the charge are far from being good con-

ductors of heat, we may assume that there exists in the charge a series of concentric hollow cylinders of gradually decreasing diameter, each hollow cylinder differing in temperature by a few degrees as the diameter grows smaller, the hottest part, of course, being the cylindrical layer next to the retort, and the coldest the core in the center of the charge. This is a convenient assumption for the purpose of illustration. In fact, such hollow cylinders do not exist separately, except as representing zones of temperature.

Now, with rapid firing, it is possible that the charge next to the retort-walls may reach a temperature above that of the reduction of zinc, and, consequently, produce some zinc-vapor, while in the center of the charge, water is being boiled off. Obviously, this would be a bad way to fire the furnace, since the zinc-gas would be thereby so diluted that condensation would become practically impossible. The same evil thing occurs through the distillation of the hydrocarbons when too much light "gassy" coal is used. Diluting gas may similarly be formed from the reduction of the iron oxide when ores very high in iron are treated.

If we had an ideal charge, perfect in heat-conductivity, it might be possible to keep all the contents of the retort at one temperature until the reaction requiring that temperature was complete; then immediately to elevate the temperature until the second reaction was complete, and so on, through the third and fourth reactions. This procedure would require, also, ideal conditions from a chemical standpoint, including a charge of such character that each of the several reactions would be practically complete at a temperature only three or four degrees above that at which it began. Such ideal theoretical conditions are beyond our reach, but may serve as a mental guide for formulating such conditions as are practically the best for any given situation as to ore and coal.

The firing of a zinc-furnace for reducing ores high in iron should be done as follows: The furnace should be heated up to, and kept at, a temperature slightly below the reduction-temperature of zinc, but as near that point as possible. This, in the course of an hour and a half or two hours, will bring all the contents of the retorts to a uniform temperature of slightly below 1,020° C. Below this temperature the reduction of the

iron oxide is largely completed. After this has been accomplished, the furnace should be fired for the reduction of zinc oxide.

If the reduction of the iron oxide and the reduction of the zinc oxide proceed simultaneously, the evolution of so much carbon monoxide and dioxide from the reduction of the iron oxide would sweep the zinc vapor through the condenser and burn it at the mouth. This is exactly what happens with too-rapid firing. The bright or so-called "angry" flame, burning the zinc with brilliant white fumes, while yielding practically no condensed metal, is the practical fact of which the above paragraphs are the explanation.

Through both special experiments and practical experience in zinc-smelting, I have found that the iron oxide has different degrees of reductivity, varying even more than that of zinc-ores, according to the way they were originally deposited geologically and the way they have been roasted. This result corroborates the observations of Sir Lowthian Bell. A hard, dense zinc-ore that is hard to roast, and gives a product not very porous, is naturally more difficult to reduce than one of a porous nature, which has been roasted at a low temperature. If, as sometimes happens, a zinc-ore is roasted at such a temperature as to form an incipient slag—for example, an iron silicate—and also compounds of its different constituents, such as zinc ferrate, zinc silicate, zinc aluminate, and lead silicate, the reduction of such an ore, so roasted, is retarded, its reductivity being decreased, because the compounds of zinc oxide are more difficult to break up than the oxide itself. Moreover, the particles are shrunk and cemented more closely together by the heat, just as a fire-brick, under the action of high heat, contracts and hardens; and their reductivity is thus decreased for physical reasons.

Thus it may be said that there are two kinds of work to be done in the reduction of zinc oxide. One is chemical work; the tearing of the atoms of zinc and oxygen away from each other against the force of affinity. The other is the work of tearing the molecules of zinc oxide from one another. This is physical work. Any agent that changes the aggregation of the molecules so as to make it denser increases the physical work to be done in reduction.



The formation of iron silicate in roasting is especially bad; for it is not easily reducible, and is itself a slag already formed, which will pick up other slag-materials, and, collecting in the bottom of the charge, quickly cut a hole through the retort. For this reason, several zinc-plants in Kansas charge carbonates "green" into the retort, even though their bulk is greater.

Metallic iron as an iron-sponge does not, in my opinion, have very deleterious effects, provided sufficient fine clean coal is present. In the first place, the iron seems to draw up in globules in the pores of the charge by capillary attraction, and to be held there as water is held by a sponge. Not only is its melting-point high, but it has no great chances to form alloys with other metals.

The iron sulphide, on the contrary, is really the most corrosive part of a charge, whether present in the charge as pyrites in the original coal or pyrites not roasted in the ore, or formed by the iron sponge acting on the zinc sulphide. At from 1,100° to 1,200° C. iron sulphide will dissolve fire-clay practically as hot water dissolves sugar. Several times, in my small electric crucible-furnace, I have added pieces of a retort to molten iron sulphide, and observed a considerable evolution of sulphur dioxide, suggesting that an iron silicate formed. This product analyzes 3 or 4 per cent. S and is partially a sulpho-silicate.

Moreover, molten iron sulphide is extremely mobile and will penetrate the pores of a retort, where it forms, under the oxidizing flames of the combustion-gases, an iron slag, and cuts a hole through the retort. Then the metallic iron in the charge is oxidized and furnishes enough iron oxide for the formation of more slag. In the course of four or five days, if slagging has happened first on a retort in the top row, all the retorts vertically under the unfortunate one will be cut out and spoiled by the slag dropping down from it. The whole trouble is probably caused by an accidental and local excess of iron sulphide in one portion of the charge, due to poor roasting or poor coal, or both, and an uneven "mix."

A phenomenon of zinc-smelting which puzzled me for a long time is what is known as the "setting" of the furnace. When a furnace is fired up so rapidly at first that a great deal of zinc cannot be condensed but burns at the mouth of the

condenser, the furnace-man will often suddenly reduce the temperature, to stop this loss of zinc. If this change be too marked, the charge in the furnace becomes "set," and it is impossible to get the zinc out, even though the temperature be raised to a point much above that ordinarily employed. The reason is, that a thick heavy slag is thus formed, and, once formed, contracts on cooling, and encircles the particles of ore and coal. If the temperature had been brought up slowly, the slag would never have been formed, or would have been formed only at the end of the shift, when the charge was "dry" of zinc.

This suggests another point. While a thick slag prevents reduction, the formation of a very liquid slag facilitates it, probably by bringing the reacting substances into igneous solution, so that they can act on each other. In American zinc-practice, it is deemed inadvisable to form slag at any time, if it be possible to prevent it, but in Europe, occasionally, the residues are tapped from the retorts as a liquid slag.

This brings us to the essential difference between European and American zinc-furnace practice. By a sort of natural evolution, the practice of each country has tended along the lines suited to the commercial environment. In Europe, coal is expensive and labor cheap. In the United States, gas and coal are very cheap, labor is dear, and our workmen have not had the training in zinc-smelting of those in Germany and Belgium, where this calling has often been followed in the same family for three or four generations.

Consequently, the practices are radically different. The German metallurgist charges a small amount of coal, with a roasted zinc-ore averaging something under 50 per cent. of zinc, into muffles holding from 80 to 100 lb. of ore. This is fired in regenerative furnaces with great care. At the end of the shift, the residues are carefully scratched up by hand, sometimes without taking the condenser down, and the retorts are sometimes charged again through the mouth of the condenser. A great deal of labor is always used per retort.

In the United States, the retorts are cylindrical and are charged very rapidly with a material high (in the case of Joplin ores over 70 per cent.) in zinc. The furnaces are fired very extravagantly, usually with natural gas. At the end of the shift, the residues are blown out by steam or water. In

Kansas, the aim is always to make a charge that contains so much coal and so little iron sulphide as to be non-corrosive, and leave "dry" residue—one that contains a minimum of slag. Very little scratching or cleaning of the retorts by hand-rabbling is done in this country. It will be seen that the practice of Europe and of America is different in these respects, by reason of totally unlike conditions in the two regions.

In the treating of ferruginous zinc-ores from Leadville and elsewhere, American practice has been simply a refinement and a carrying-out to the extreme of the method pursued with Joplin ores. The attempt is always to make a non-corrosive charge which, by reason of its large amount of fixed carbon, will also have a maximum reductivity at as low a temperature as possible. The criterion of this charge, for low-grade ores, is recognized by the practical zinc-smelter in the glowing and brightening-up of the residues when the condensers are "knocked down" in the morning, at the end of the shift. If the residues then glow, it is, of course, a sign of the presence of active particles of carbon, to be attacked by the oxygen of the air which rushes into the retort. Consequently, the charge, at the end of the shift, still possessed considerable reductivity, and it was not necessary to use intense heat to reduce and distill the zinc. Did the charge contain no remaining active carbon it would not glow. The zinc-smelters have almost a superstition about this glowing or "looking red" in the retort; and it is convincing to see that it has good chemical reasons.

Another fact about zinc-reduction which I have never seen noticed, is that carbon-deposition occurs around the iron oxide just as it does in the shaft of an iron blast-furnace, and that this deposited carbon is very active in reducing the particles of zinc oxide.

The reaction of the iron-sponge on both zinc oxide and zinc sulphide increases, of course, the amount of zinc distilled. These reactions are both completed below  $1,200^{\circ}\text{C}$ . The iron is formed as an iron-sponge through the reduction of the iron oxide by the carbon of the charge. For this reason, magnetic zinc-blende, the so-called "marmatite," is very active.

Another characteristic of the reduction of zinc oxide is the distillation of the heavy tars in the coal. These heavy tars are distilled at about the temperature at which zinc is reduced, and

are retained in the condenser, where they form a solid mass, and in time choke the condenser. I have never seen this reason given before; but it is undoubtedly the chief reason why accretions are slowly formed on the sides of the condensers, which have to be cleaned out by the "connie boy."

The coal for a zinc-charge should have maximum heat-conductivity, "reductivity" (*i. e.*, active energy in reduction), and percentage of fixed carbon per cubic foot; and minimum proportion of hydrocarbons and of ash (the ash containing, moreover, a maximum of aluminum silicate). Finally, it should be low in price.

To combine all these good qualities in one kind of coal is impossible, and hence it is advisable to use three or four different kinds, one serving one purpose, and another another. For instance, petroleum coke, the residue from the distillation of oil, contains from 94 to 96 per cent. of carbon, and less than 1 per cent. of ash; but it carries 3 or 4 per cent. of heavy hydrocarbons. This would be an ideal reducing-agent for zinc, did not its hydrocarbons choke up the condenser; and therefore it should not be used for more than one-sixth of the total fuel.

"Dead coal," from the "strip-pits" of Missouri and Kansas, has carbon of good activity. The ash is also pretty infusible, because the sulphur has been extracted through weathering of the coal. It yields, however, a very high amount of gas, and therefore too much of it should not be used. Moreover, it is always well to use several kinds of coal, so that accidental poor shipments of one kind will be "averaged out."

All things considered, probably the best reducer for a zinc-charge is anthracite slack, having less than 0.6 per cent. sulphur and an ash which is nearly an aluminum silicate. It is, however, usually too expensive for use except in a few localities.

For maximum reductivity, neither the zinc-ore nor the reducing-material should be too fine. With coal, and ore finer than 60-mesh, there will be channeling of the gases of reduction, and the very efficient reducing-action of hydrocarbon vapors and carbon monoxide will be lessened. Besides, there is a "back-pressure" of these gases, which retards reduction.

The ideal of American zinc-practice should be to produce a charge of maximum reductivity with an infusible residue. If

this were attained, it might be possible to use much larger re-torts, or possibly a gas-fired continuous furnace.

In this paper the word "reductivity" has been applied to the charge, the reducing-agent, and the ore, while possibly a stricter phraseology should have been used.

In conclusion, I want to express my appreciation of Dr. Percy's early work on zinc. Having repeated and extended all his experiments, I feel bound to testify that they reached the heart of the subject, and established principles not superseded by later progress. This is not true of all such pioneer work, however creditable it may have been in its day; and when it is true, it deserves to be publicly declared.

I wish, also, to acknowledge my indebtedness for valuable suggestions to Messrs. C. A. H. de Saulles, John Nett, Walter J. Chapman, and many others.

## Piping and Segregation in Steel Ingots.

A discussion of Mr. Howe's Paper presented at the London Meeting, July, 1907, and published in *Bi-Monthly Bulletin*, No. 14, March, 1907, pp. 169 to 274.

ALFRED C. LANE, Lansing, Mich. (communication to the Secretary \*):—Prof. Howe's paper on piping and segregation in steel ingots,† is, in my judgment, very interesting and suggestive to geologists, as well as metallurgists. For an igneous rock-mass is but an ingot, in the case of intrusives generally "bottom cast" (p. 225). Its general dimensions are also fixed by those of a shell of frozen material, while most of it is hot and molten (pp. 174 and 178). The question whether rock-magmas contract or expand in solidification is also in doubt; and the same lines of argument apply (p. 175), but Howe's explanation (p. 178) is also applicable to the igneous rocks, since these likewise have a tendency to form cavities which may remain as vugs or druses or be filled up by pegmatites or aplites.

Prof. Howe's discussion of the location of the pipe is also applicable and the five factors which limit the same, though of course in the case of igneous rocks the pressure may be more than the atmospheric (p. 211). Blow-holes (pp. 203, 240) correspond somewhat to amygdules, and the ice-ingot bubbles (p. 241) to pipe-amygdules. The migration of metals below the melting-point (p. 214—also described by Dr. Koenig before the Lake Superior Mining Institute) is obviously important in the science of ore-deposits. The walls of the pipe, sometimes smooth and sometimes lined with crystals (pp. 216, 217, 220, 221), might also be matched among the cavities in igneous rocks. Druses of crystals, continuous with those making up the igneous rocks, have been described, for instance, by Patton. It is interesting to notice that there is sometimes (pp. 220, 221) a sort of transition-zone, well shown by the meli-

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\* Received May 4, 1907.

† The page-numbers in parentheses, throughout this contribution, refer to *Bi-Monthly Bulletin*, No. 14, March, 1907.

lite slags of the copper-country, in which crystals occur with rounded faces, and heavily charged with cavities. The crystalline forces of the mineral have been able to distort the round shape of the drop somewhat, but not perfectly to free it from its mother-liquor. The "pine-tree" crystalline growths (p. 220) find frequent analogues in what are known as arborescent forms in rock-forming minerals.

The discussion of segregation, its causes and its restraining factors (p. 248), has an obvious application, almost word for word, to magmatic segregation. For instance, the segregation of the heavier augite in the ash-bed porphyrites is below the center, as in the ice ingot (p. 234). But when Prof. Howe comes to discuss the effect of the rate of cooling, I do not think that he has fully given due weight to the possible effects of the temperature of pouring relative to that of freezing; and it is along this line that I venture some suggestions which may have value for him and his readers.

In the theory of cooling and its effect on grain which I have developed,<sup>1</sup> the essential points, other things being equal, are these: that the slower the cooling the coarser the grain; that the slowest rate of cooling at the time of freezing might be at the center or at the margin or somewhere between; that this depends most directly on the country-rock (or mold<sup>2</sup>), the distance to which the same is affected (whether sand or iron molds), the temperature of solidification (or freezing), and the initial temperature (or that of pouring). It may easily be that in considerably superheated magmas (ingots), or those in which the country-rock is already hot and a poor conductor (a mold already heated, or made of a non-conductor, such as sand), the locality of slowest cooling at the time of freezing will be somewhere near the margin. In fact, it may have any position, according to circumstances. Hence, the center or axis of the ingot may possibly be cooling much more rapidly than other parts, at the time of freezing. These relations are illus-

<sup>1</sup> *Report of the Geological Survey of Michigan*, vol. vi. (1893-97); *Fifth and Sixth Annual Reports of the State Geologist of Michigan* (1903, 1904). See also *Bulletin of the Geological Society of America*, vol. xiv., pp. 369 to 406 (1902); *Journal of the Canadian Mining Institute*, vol. ix., pp. 210 to 217 (1906).

<sup>2</sup> In this passage, the phrases in parentheses are intended to indicate the conditions and factors considered by Prof. Howe, which correspond to those enumerated by me, in discussing the analogous geological problems.

trated by curves of cooling, which I have elsewhere published. If this be true, those of Prof. Howe's statements which imply that the center must *necessarily* cool more slowly than the outer part (p. 179, § 7; p. 194, last paragraph; and a considerable part of the discussion of segregation from p. 243 on) must be qualified, or modified. It seems to me quite possible, for instance, that in the case of Fig. 28 (p. 240) the ring of blow-holes might be due to the fact that that was the ring of slowest cooling, and that, both at the margin and the center, the cooling was too fast *at the time of freezing* to allow the gas to become disentangled. In the same way, it is possible that segregation may take place up to the distance from the margin which is that of the zone of slowest cooling, while, from this on, the more rapid cooling at the time of freezing might tend to check the continuance of this action, as is already brought out by Prof. Howe (pp. 248-251). This would account for some of the contradictory evidence cited by him (pp. 252-254). I have called attention to possible cases of this character in the paper for the Canadian Institute.<sup>3</sup> The essential thing to remark is, that in considering such evidence as that of the temperature of pouring (§57, p. 252), the superfusion ratio is a most important factor, without knowledge of which it is hardly possible to discuss the data to advantage.

PROF. HENRY M. HOWE, New York, N. Y. (communication to the Secretary \*):—The points of likeness to which Dr. Lane calls attention, between the solidification of metallic ingots and that of rock-masses, are full of interest. I have elsewhere examined these resemblances,<sup>4</sup> and in my lectures I have always insisted on them, and found them very effective in fixing the students' attention.

I am at a loss to understand how Dr. Lane can have thought that I asserted or implied that the cooling of the center in the act of freezing is slower than that of the outside. Why, the very essence of my explanation of the formation of the pipe is that the central parts, when they are freezing, are cooling faster than the outer parts. (§§ 9, 10 and 11, pp. 180 to 182, *Bi-Monthly Bulletin*, No. 14, March, 1907.)

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<sup>3</sup> *Journal of the Canadian Mining Institute*, vol. ix., pp. 210 to 217 (1906).

\* Received July 26, 1907.

<sup>4</sup> *Iron, Steel and Other Alloys*, pp. 2 to 8.



In their solidification, steel ingots differ in one very important respect from rock-masses—viz., that the steel ingot is cast when only very slightly above its freezing-point into a mold which is habitually cold, so that the outer layers begin to freeze almost instantly, and that, at the beginning of the solidification, their cooling must be much faster than that of the central parts. I quite agree with Dr. Lane that, when the central parts in turn come to freeze, they may be cooling faster or they may be cooling more slowly than the outer parts. If they are cooling faster, a pipe should form; if more slowly than the outer parts, the pipe should be absent, as it very often is.

What I was trying to do was to explain how it comes about that the pipe forms, and I pictured the conditions which lead to its formation, among them the faster cooling of the center than of the outside at the time when the center is freezing. I by no means intended to imply that this pipe-forming condition, which is essential to pipe-forming, must always exist. I might indeed have done well to affirm that it need not, though that would have been foreign to the argument before us.

When we turn to segregation, the important matter is not the rate of cooling of the central parts at the time of their freezing, but the fact that their freezing occurs later than that of the outer parts; not rapidity, but priority.

ALFRED C. LANE, Lansing, Mich. (communication to the Secretary\*):—The misunderstanding of the implication of certain sentences of Professor Howe's paper is not so much to be regretted, since it has drawn out the valuable and clear supplementary statement. I did not know enough about the technique of steel-ingot casting to take for granted that the ingot is "cast only when very slightly above its freezing-point," but had supposed that the amount of excess of temperature or superfusion might be, as it is competent to be, an important factor.

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\* Received August 23, 1907.

## Geology and Mining of the Tin-Deposits of Cape Prince of Wales, Alaska.\*

BY ALBERT HILL FAY, B.S., E.M., NEW YORK, N. Y.

(Toronto Meeting, July, 1907.)

IN giving a sketch of the geology and mining of the tin-deposits of Cape Prince of Wales, a short description of the geographic and climatic conditions may be of special interest on account of this being a part of the world of which very little is known, even by the reading public. As shown in Fig. 1, the location of the Cape is lat. N.  $65^{\circ} 35'$  and long. W.  $168^{\circ}$ . It is bounded on the north by the Arctic ocean; on the west by Bering strait and on the south by Bering sea. It is the westernmost point of the mainland of North America, and to the west, across the strait, one can see East Cape, Siberia, which consists of a rugged, steep coast of granite cliffs.

The climatic conditions are of interest because of the part they have had in the surface geology, and also because they affect mining from an economic standpoint. In connection with the climate and geography, it does not seem out of place here to quote a few lines from the prologue of *The Wandering Jew*, written by Eugene Sue, under the caption "The Land's End of Two Worlds."

"The Arctic Ocean encircles with a belt of eternal ice, the desert confines of Siberia and North America—the uttermost limits of the Old and New World, separated by the narrow channel known as Bering's Straits.

"To the north, this desert is bounded by a ragged coast, bristling with huge black rocks. At the base of this Titanic mass lies enchained the petrified ocean (Bering sea) whose spell-bound waves appear fixed as vast ranges of ice mountains, their blue peaks fading away in the far-off frost-smoke, or snow-vapor.

"Between the twin peaks of East Cape, the termination of Siberia, the sullen sea is seen to drive tall icebergs across a stream of dead green. There lies Bering's strait. Opposite, and towering over the channel, rise the granite masses of Cape Prince of Wales, the headland of North America.

"These lonely latitudes do not belong to the habitable world."

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\* Submitted, also, with the consent of the Council of the Institute, as a thesis in partial fulfillment of the requirements for the degree of Master of Arts, to the Faculty of Pure Science, Columbia University, New York, N. Y.

Such is Sue's description of this barren and desolate country, and it is so true, that any navigator upon the high seas, who had read the prologue, could not do otherwise than recognize the place though he had never previously been here.

During eight months in the year no boats can reach Cape Prince of Wales. In the summer, the United States mail arrives twice a month; and in the winter there is a weekly mail

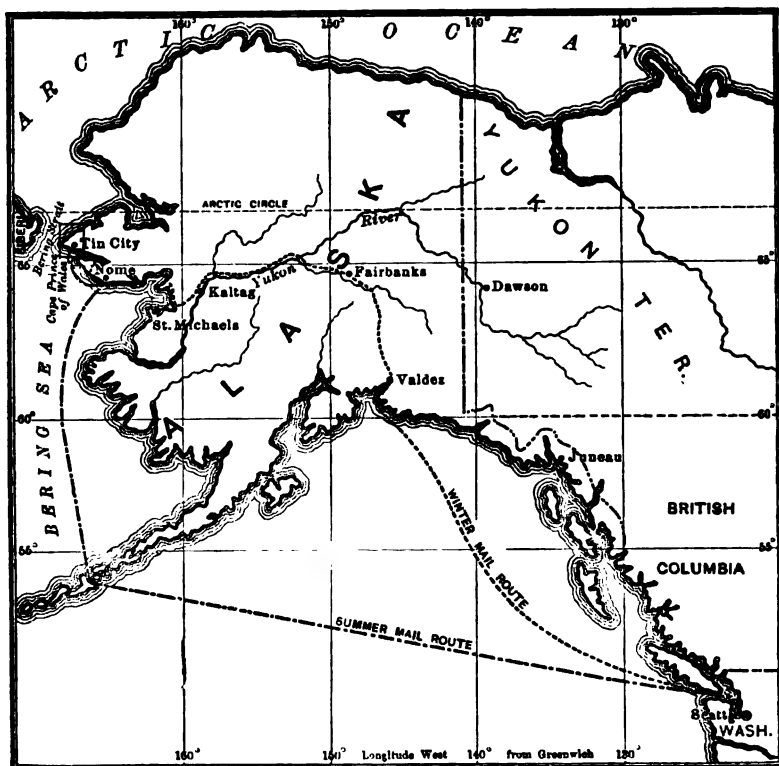


FIG. 1.—SKETCH-MAP OF ALASKA.

service from Nome. The winter mail is carried on horse-sleds from Valdez to Fairbanks over the trail shown in Fig. 1; thence down the Yukon river to Kaltag; across the portage to Unalakleet; and along the coast line to Nome and Tin City. From Fairbanks to Tin City the mail is carried by dog-sled. The total distance from Valdez (the winter sea-port) is a little more than 1,400 miles. Mail from the United States will reach the Cape in from 60 to 80 days. There is a telephone line to

TABLE I.—*Daily Temperatures at Tin City, Alaska, 1906-1907.*

DAY OF MONTH.																																Average.
																																44.7
																																37.6
																																30.6
																																10.8
																																6.6
																																7.5
																																-22.2

Nome, where it connects with the United States military telegraph line to Seattle.

#### CLIMATE.

The summers are comparatively cool,  $60^{\circ}$  F. being the highest temperature, while  $45^{\circ}$  is about the average from June 15 to Sept. 15. At Cape mountain a very large part of the time (at least one-half) there are heavy fogs and drizzling rains, which make it bad for all outside work. The wind blows very hard at times, adding a great deal to the inclemency of the weather. Freezing temperatures, with snow-storms, usually set in about Sept. 15. Navigation for small boats from Nome is uncertain after Oct. 20, although in 1906 they continued to run until Nov. 10. By Dec. 1 the sea is usually sufficiently frozen to permit traveling by dog-sled (Fig. 8) on the ice near the beach. The winters are noted for very severe blizzards of snow-ice and high winds. Yet the temperature does not drop so low as in more inland places. The lowest temperature for the winter of 1905-6 was  $-45^{\circ}$  F. During these blizzards, which often last ten days at a time, it is almost impossible for man or beast to endure the icy blasts as they hurl themselves down upon him from the polar regions. The changes in temperature are very sudden, as shown in Table I., which I compiled from daily observations from Aug. 9, 1906, to Feb. 23, 1907. In 24 hr. during Jan. 8 and 9, 1907, there was a drop of  $43^{\circ}$ , and the maximum range for the period observed was  $102^{\circ}$ . February was a cold month, with a continuous blizzard lasting about two weeks.

Table II., the weather record<sup>1</sup> covering a period of years at the Government station at St. Michaels, is here given to show something of conditions at that place. St. Michaels is about 225 miles SE. of the Cape, and is the place nearest to Tin City where records have been kept for any length of time.

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<sup>1</sup> Gravel and Placer Mining in Alaska, by C. W. Purington, *Bulletin* No. 263, U. S. Geological Survey, pp. 48, 49 (1905).

TABLE II.—*Rainfall and Temperature at St. Michaels.*

Month.	Rainfall. Average 7 yrs. 6 mos.	Rainy Days.	Temperature. Average 11 yrs.
	Inches.		°F.
Jan.	0.9	8.1	7.4
Feb.	0.2	5.5	-2.3
Mar.	0.5	7.4	8.9
Apr.	0.4	7.8	19.9
May	1.3	9.1	33.1
June	1.5	10.4	46.3
July	2.5	13.6	53.6
Aug.	3.3	16.7	51.9
Sept.	4.0	18.5	43.9
Oct.	1.7	11.4	30.5
Nov.	1.2	11.4	15.6
Dec.	0.8	6.9	4.8
Total.	18.3	126.8	Average 26.1

During seven months of the winter the climatic conditions permit little, if any, outside work, although freighting, such as hauling ore, could be performed during about half of the winter season. Underground work can be carried on without difficulty during the entire winter, but it is absolutely necessary to get all supplies in before Oct. 1. The ground is frozen very deep, and some prospect-shafts and tunnels from 80 to 100 ft. below the surface are still in the frost-zone. No well-water has been found; and, for domestic purposes, the supply comes from thawing the snow as needed. Water can be obtained near the beach at a depth of 12 ft., but it is too salt for any purpose other than milling. A supply of water for mill use during the summer can be obtained from the melting snows on the mountains and needs no pumping.

The operation of any concentrating-plant in which water takes an important part can be carried on only during four months in the summer, since cost of fuel will be prohibitive in winter.

#### VEGETATION.

On account of the long winters and very short, cool summers, it is surprising to find such a variety of plants. There are no trees, nor even shrubs. The vegetation consists almost exclusively of moss and small flowering plants, of which the forget-me-not is abundant. I have seen during the short sum-

mer 30 or 40 varieties of these delicate flowers, nearly all having bright colors and most fragrant odors. It is not uncommon to find these tender plants growing alongside of deep snow on the slopes of the hills. There are several species of moss, which furnish food for the reindeer, and though grass is scarce, enough plants grow to give the low, flat places a bright green appearance during August. The sunshine in summer lasts from 18 to 23 hr. a day, and under its influence plants come out very quickly after the snow leaves the ground bare, and mature quite rapidly.

#### GEOLOGY.

Fig. 2, of Cape mountain, gives a good idea of the topography of this portion of Seward peninsula. When the geology of

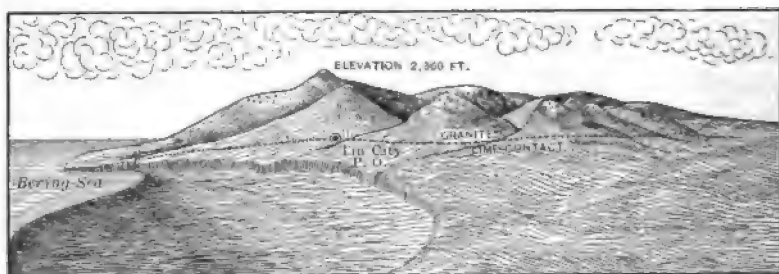


FIG. 2.—CAPE MOUNTAIN, FROM THE EAST, SHOWING TOPOGRAPHY.

the country covered by the map, Fig. 3, is interpreted we are led to the belief in a very marked eruptive period, followed by a long time-interval, during which erosion has played an important part. The western end of the mountain, next to the Cape, consists of a granite knob 2,300 ft. high, known as Cape mountain, which rises so abruptly from Bering sea that there is not enough strand line for even a foot-path.. This is indicated in Fig. 8. To the north the mountain slopes gently to the Arctic ocean, where there is quite a broad margin of low ground, formerly sand-spits, but now covered with tundra. These sand-spits are still forming, and inclose a series of lagoons along the coast, the largest one being known as Lopp Lagoon. East of Tin City there is a broad tundra-covered plateau extending to the York mountains, with an elevation of from 300 to 400 ft. above sea-level. This plateau is very

much dissected by short valleys extending north and south, which, during the summer, are water-ways for the small streams. On the western side of this plateau, and against the

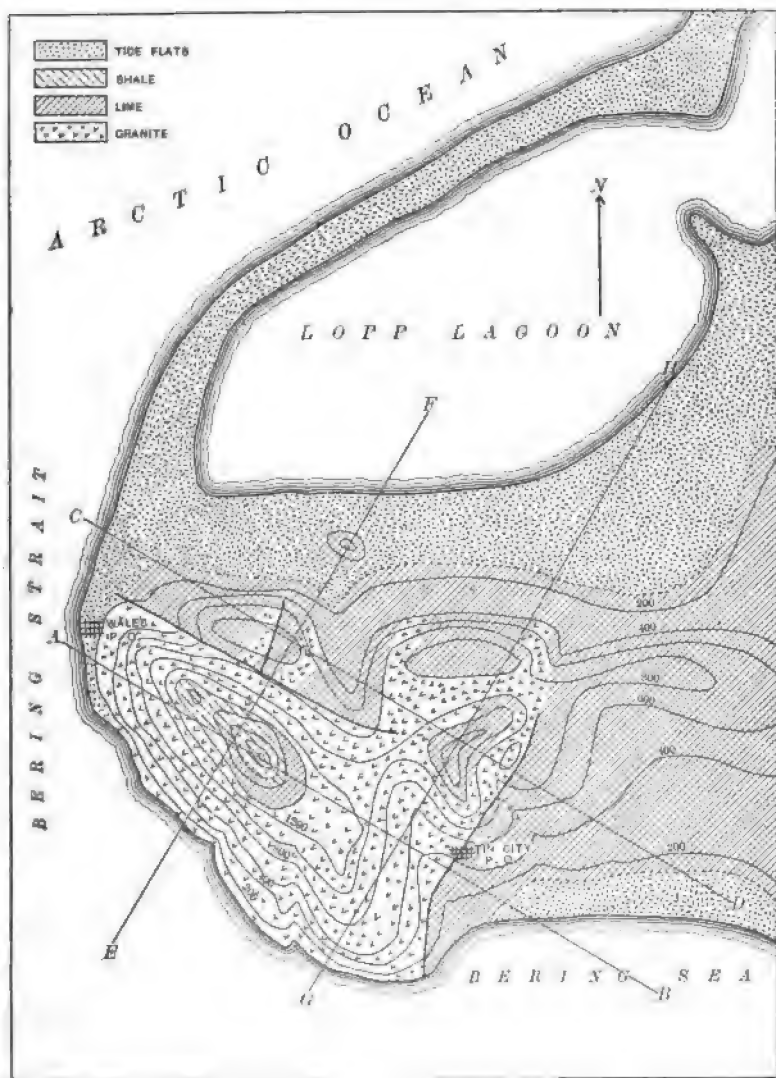


FIG. 3.—GEOLOGICAL MAP OF CAPE MOUNTAIN, CAPE PRINCE OF WALES, ALASKA. (Scale:  $\frac{1}{4}$  in. = 1 mile.)

granite mountain-mass, are three limestone terraces, which have the appearance of ancient beach-lines. The lower one is now very near the present beach, and no doubt the present



narrow margin along the coast is, in places, of very recent formation. The upper terraces I am inclined to consider as the remnants of a monocline—or the west limb of an anticline, in which the erosion has progressed westward from a N-S. axis of uplift. Six or eight miles east of these terraces, which are near the granite-lime contact, the strata dip in the opposite direction, and thus indicate the presence of the two limbs of an anticlinal fold.

The surface of the more elevated and mountainous portions shows the effect of frost in a very marked degree. The freezing and thawing process has gone on so long, and the outcropping rocks have been broken up to such an extent, that practically all the surface is covered with loose fragments to a depth of from 5 to 20 ft. On the steep mountain-slopes this débris creeps so much that when float-ore is found, one can hardly even guess its point of origin. Except for some of the granite monoliths and an occasional limestone cliff, outcrops are scarce, making prospecting very difficult.

There are a large number of these granite monoliths from 20 to 75 ft. high and of grotesque shapes, standing in clusters, as shown in Fig. 9. One of these columns, Fig. 10, has the profile of a man's head and is named the "Wandering Jew."

The granite rocks, Fig. 9, are exceptionally good examples of wind-erosion. These rocks stand in approximately a N-S. line, with the north at the left of the photograph. By close observation, it will be noticed that the left side of these rocks is very much rounded and cut away, while the right or south side is very angular. The prevailing wind at this place is from the north, and it usually blows with a high velocity. At times the force is so great that it is almost impossible for a man to keep on his feet. In summer the wind carries more or less sand, which acts as a sand-blast on these giant rocks, and in winter vast quantities of snow and ice are carried by the wind and assist, though to a lesser extent, in the destruction of the monoliths. The view of the Wandering Jew, Fig. 10, does not show the work of the wind, because this lone rock stands on the side of a hill where it is very much protected.

The granite is somewhat coarse and light colored. The feldspar crystals vary in size from a small fraction of an inch to 2 in. long. The hornblende crystals are few and small, and

biotite is the prevailing dark mineral. The main body of granite has the appearance of a boss, on the top of which is a lime and shale cap. From this main boss extend intrusions into the lime between the bedding-planes, and form sills which are nearly horizontal. There are also vertical dikes, from a few inches to 30 ft. thick, radiating from the central core and extending into the lime. These dikes appear to have the same texture as the granite along the main contact, and are probably contemporaneous with it. At one place I found a dike of rhyolite-porphry cut through the coarse granite. The contact between the two masses is very sharp and showed no decomposition of either. At the contact the rhyolite and granite were actually fused together.

There were at least three periods of disturbance after the deposition of the limestone: 1. Eruption of the main granite-mass. 2. Intrusion of rhyolite-dikes. 3. Intrusion of basalt-dikes.

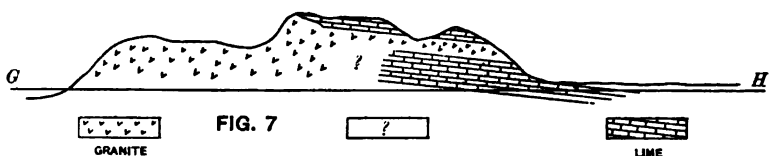
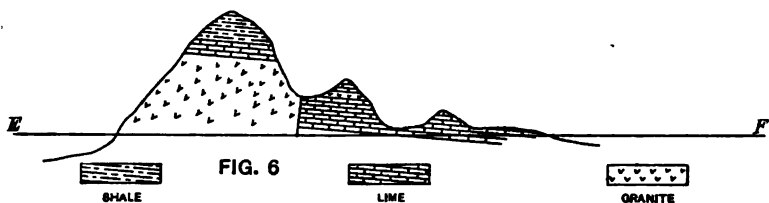
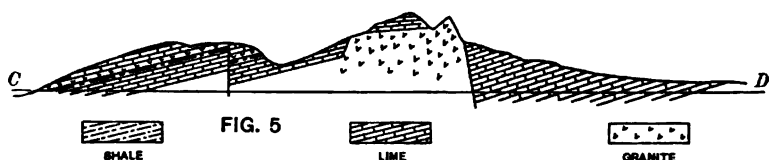
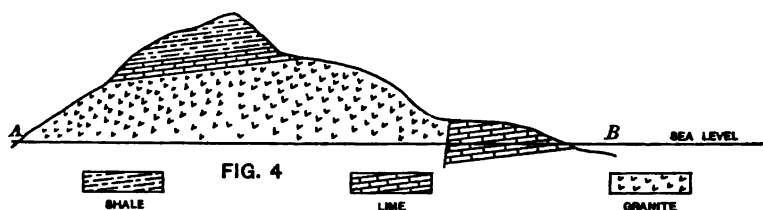
After the limestone had been deposited came the great uplift, which formed the mountain, and tilted the limestone-beds, shown in Figs. 4, 5, 6 and 7. Then came a period of rest and the whole mass solidified. Following this was very likely a long time-interval, during which erosion played an important part. Then came the intrusion of rhyolite-dikes, as mentioned above. I also found one basalt-dike which cut through both the granite and lime, at the contact of the latter. No place was found where the basalt- and rhyolite-dikes cut each other; but on account of the acidity of the rhyolite it is probably the older of the two. The basic rocks have a lower freezing-point. It is not at all likely that the acid and basic dikes were intruded at the same time, for the two observed were only a few yards apart.

The limestone still retains its bedding-planes, and is generally of fine grain and bluish color. In places near the contact with the granite it has become crystalline, while at others it is more siliceous, with stringers of quartz between the bedding-planes; a large amount of the lime at the contact near the beach, as well as at the contact near the top of Cape mountain, shown in Fig. 11, has altered to wollastonite. I found neither garnet nor fluorite in this contact-zone.

There are four places where there is still some limestone on

top of the granite, as shown in Fig. 3. Toward the top of Cape mountain, as well as near the Indian village, the limestone becomes more shaly, and even schistose in character.

I found three fossils in the lime, one near the Indian village (Wales P. O.) and one three miles east. Another was found



FIGS. 4, 5, 6 AND 7.—GEOLOGICAL SECTIONS, CAPE MOUNTAIN.

on the beach about two miles south of the last one above mentioned. All three were alike and silicified, but no report has yet been made. Mr. A. J. Collier has reported that the fossils from this section belong to the Carboniferous age.<sup>3</sup>

<sup>3</sup> History of Explorations and Surveys in Geography and Geology of Alaska, by A. H. Brooks, *Professional Paper No. 45, United States Geological Survey*, pp. 206, 217, 224 (1906).



FIG. 8.—BERING SEA ICE, EXTENDING DIRECT TO THE BASE OF THE GRANITE CLIFF, WITH MAN AND DOG-TEAM IN THE FOREGROUND.



FIG. 9.—MONOLITHS OF WEATHERED GRANITE ROCKS, FROM 25 TO 75 FT. HIGH.



FIG. 10.—THE “WANDERING JEW,” ABOUT 40 FT. HIGH.



FIG. 11.—LIMESTONE BEDDING NEAR TOP OF CAPE MOUNTAIN. THE WHITE STREAKS, MARKED “W,” ARE WOLLASTONITE.

As shown in Figs. 4, 5, 6 and 7, the limestone dips to the west at an angle of  $5^{\circ}$  to  $15^{\circ}$ , with a strike of N.  $10^{\circ}$  E.

Near the beach the contact-line between the limestone and granite is vertical, and about two miles farther north it dips east  $80^{\circ}$  (Fig. 5). One-half mile farther to the north it dips  $60^{\circ}$  W. The slickensides show that some movement has taken place along this line.

In addition to the main contact, there are occasional bodies of limestone which have been caught in the molten granite, and are now held as inclusions. It is alongside one of these that the best tin-ore has been found. This particular body of limestone is about 20 ft. thick.

#### TIN-DEPOSITS.

At a number of places on Cape mountain a little float tin-ore has been discovered, but not enough to be of importance. The lode-deposits are also small, at least as far as present developments show. Much of the granite carries traces of tin, and occasionally small stringers of cassiterite exist along very fine fractures in it. In one case a stringer from 1 to 2 in. thick was found which was nearly vertical. This stringer passed through the granite, and also along the bedding-planes of the limestone, showing the tin to be later in origin than the limestone.

The cassiterite found in the limestone was crystalline and exhibited good faces. Associated with it was quartz and limonite. The stringer of cassiterite in the granite was more massive and had the appearance of a local enrichment. There was no marked line of contact; the center was almost pure cassiterite, and passing from this to the granite the tin oxide seemed to give place to the biotite and feldspar until the normal granite was reached on either side. At one point of contact there is an iron selvage varying from a few inches to 4 ft. thick. The iron oxide (limonite) is quite pure and contained no tin. The tin at this place seems to be in the granite.

Along this granite-limestone contact there is an excellent example of the formation of tourmaline. All the necessary conditions are provided. The granite above the limestone lies almost horizontal, and must have provided, when in the molten and viscous state, practically a reverberatory furnace. This overlying mass, by reason of its weight, would retain emanating gases under pressure. All the constituents of tourmaline are

at hand: lime in the limestone; iron, magnesium, aluminum, sodium, potassium, boron and silicon in the granite. Boric fluoride is very readily absorbed by water (700 volumes of  $\text{BF}_3$  to 1 of  $\text{H}_2\text{O}$ ), and in this way it may have been supplied by the crystallizing granite. The tourmaline has formed on the lower side of the granite and exhibits well-developed crystals in quantity. As depth in the granite is gained, the amount of tourmaline diminishes. Below the tourmaline-granite, and resting immediately on the limestone, is a quantity of filling consisting largely of limonite and free quartz. This iron has undoubtedly been precipitated here as a sulphide, and is now the product of oxidation. This change has been wrought when climatic conditions were milder than now, for it is all in the frozen zone.

The presence of an occasional stringer of cassiterite in the granite, now in place, would indicate that the float tin-ore on the surface is simply a residual product of decomposition of the granite. It might be used as proof that there are still rich bodies of ore here; but it is more reasonable to regard the float as representing stringers and veinlets that have existed in bygone ages. Erosion has been great, and it is not an easy matter to say to what extent these deposits have been carried away. Placer tin-ore is found in many places on the Seward peninsula, and no doubt all has the same origin.

On the whole, not enough work has been done to obtain very much information concerning the size and continuance of the lode-deposits. All that can be said now is that they are not large enough to pay to work. Some of these stringers may improve as depth is gained, but that remains to be seen.

#### SAMPLING AND ASSAYING.

The assay was usually made on 100 g. of pulp of 60-mesh size obtained from the sample, which was taken to represent as nearly as possible an average value. This pulp was carefully panned until most of the gangue had been washed off, leaving a concentrate of about 10 g. containing cassiterite, with small amounts of pyrite, iron oxide and tourmaline, together with some other gangue materials clinging to them. This concentrate was then digested in nitro-hydrochloric acid for an hour, or longer, until all the soluble parts were dissolved,

leaving most of the tin oxide reasonably clean. The residue, containing some quartz and tourmaline, was then thoroughly washed, dried and weighed. A fire-assay on a number of these pannings gave an average of 70 per cent. of metallic tin, while pure cassiterite contains 78 per cent.

By practice and careful work in the panning and acid-treatment, uniform results can be obtained. I made 300 tests on various samples in this manner and considered my final concentrate as 70 per cent. of metallic tin. Though not absolutely correct, this method of assay is sufficiently accurate for testing country-rock, float-material, grab-samples from ore-dumps, and prospectors' samples. Moreover, when at a distance from a well-equipped laboratory, the best use has to be made of the tools and supplies that are available.

The charge for the fire-assay was made up as follows: 10 g. of concentrates from ore was thoroughly mixed with 40 g. of KCN (98 per cent.); 5 g. of KCN was placed in the bottom of the crucible, the charge then added, and covered with 5 g. of KCN. The time of fusion in gasolene furnace, from 15 to 25 min., gave a metallic tin button ready to be weighed. No analysis of the tin button was made to determine its purity.

Of 36 samples of granite, 18 contained a trace of tin, while 23 showed none. Those that had any tin whatever were the ones nearest the contact, or, in other words, in the outer shell of the granite. Phillips and Louis, in describing a mine in New South Wales, report that "the tin-bearing portion of the granite is practically confined to a belt that forms the outer crust of the boss."<sup>3</sup> The portion of the vein-matter which could be taken as ore for treatment has a very low tin-content.

#### MINING.

Down to the present time very little mining has been done, but there has been considerable prospecting by a half dozen concerns. A large part of this prospecting has been in the shape of open cuts and costeaning trenches, in the endeavor to find the ledge from which the float-ore has come. The surface of the ground consists of so much loose earth and boulders, that it is very difficult to obtain good results from open work. During the short summers, the ground will thaw only to a

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<sup>3</sup> *Treatise on Ore-Deposits*, Phillips and Louis, p. 668 (1896).



depth of from 3 to 4 ft.; and, below this, the digging is very hard. If the open cut is on level ground, the melting ice and snow will flood it with water, so that it is necessary either to abandon the work, or to put in a pump, before bed-rock can be reached.

Prospecting has been carried on continuously since 1902, the largest operations being those of the Bartels Tin Mining Co. The mining work consisted of a large number of open cuts from 10 to 100 ft. long, many of which, however, did not reach bed-rock; a number of short tunnels, and two shafts, one 80 ft. and one 40 ft. deep. In two or three places some cassiterite was found *in situ*. The surface improvements consist of two bunk-houses, two warehouses, a barn, a blacksmith's shop and a power-house for electric drills. A Merrill 3-stamp mill was installed two years ago, comprising one 25-h.p. Model gas-engine, a Blake crusher, a hydraulic classifier, and two Wilfley tables. The plant, which has a capacity of about one ton per hour, was operated during the summer of 1906, and a small shipment of concentrates was obtained.

The next largest company operating is the U. S. Alaska Tin Mining Co., owning a number of claims on the north slope of Cape mountain. The underground work consists of one small and shallow shaft, and a tunnel about 250 ft. long. A 10-stamp mill has been installed.

During the summer of 1906, Risley and Arrowsmith did some prospecting by the use of the calyx core-drills. Several holes were bored to a depth of from 50 to 100 ft. through lime to the granite-contact, but I do not know what results were obtained.

There are several minor prospect-diggings, but they do not seem to be important or prominent.

#### ECONOMIC CONDITIONS.

Table III. gives the "quantity" prices that the mining companies have to pay for supplies if purchased at Nome, also the corresponding prices at Seattle.

The cost of labor during summer and winter is \$5 per day, plus board and lodging. At Nome, the rate in winter is \$4 and in summer \$5 per day, including board.

The outlook for the tin-mining industry at Cape Prince of

TABLE III.—*Prices of Supplies at Nome and Seattle.*

Commodity.	Price at Seattle.	Price at Nome.	Freight from Nome to Tin City.	Freight from Seattle to Tin City.
Lumber.....	\$13 per M.	\$40 per M.	\$22.50 per M.	\$20 per ton (40 cu. ft.) by sailing-vessels. This makes the freight on hay about \$30 per ton and lumber \$25 per M.
Coal .....	\$5.90 per ton.	\$18 per ton.	\$15 per ton.	
Flour (best).....	\$60 per ton.	\$80 per ton.	\$15 per ton.	
Fresh beef.....	.....	15 to 20c. per lb.	½c. per lb.	
Eggs (30 doz. to case)	\$9 per case.	{ \$12 to \$14 } per case.	\$1 per case.	
Coal oil (10-gal. case)	\$1.55 per case.	\$3.50 to \$4.25	75c. per case.	
Hay.....	\$23 per ton.	\$47.50 per ton.	\$22.50 per ton.	
Oats.....	\$30 per ton.	\$52.50 per ton.	\$15 per ton.	
Bran.....	\$18 per ton.	\$40 per ton.	\$22.50 per ton.	
Hams and bacon.....	.....	19 to 25c. per lb.	½c. per lb.	

Wales does not seem to be encouraging. A number of shipments of tin-ore (placer) have been made from Seward Peninsula, but all were small, and in every case the amount realized on the shipment was far less than the cost of production. A large number of companies have been organized for the exploitation of the stream-tin deposits, of which many have gone out of business, only to be followed by others trying to work the same ground. So far as I know, the deposits are small and of low value. This condition, and the short working-season in summer, the high price of supplies, freight and labor, combine to retard the progress of any concern that has the production of tin-ore as its object. Similar conditions apply also to all the "quartz" tin-mining, by which term the miners mean tin-ore *in situ*. Not only is the ore low grade, but the quantity is a very uncertain factor. With a large quantity of ore, it might pay to work values of 2 per cent. of metallic tin, in spite of the high cost of everything that enters into its production. Mr. Hess, in speaking of the tin-deposits of the Cape, says: "It seems safe to figure that under present conditions nothing less than 2.5 per cent. ore can be worked with a reasonable assurance of profit." The following values of ores

<sup>4</sup> In *Bulletin No. 284, United States Geological Survey*, p. 156 (1905).

worked at various places have been reported:<sup>5</sup> Mt. Bischoff, Tasmania, 1.25 per cent. of Sn; Stannary Hills M. & T. Co., So. Australia, 3.12 per cent. of SnO<sub>2</sub>; Lancelot Lode, Queensland, from 3 to 4 per cent. of SnO<sub>2</sub>; Bolivia, "Under favorable conditions, [ores] as low as 3 per cent. may be worked at a small profit." Dolcoath, 2 per cent. of black tin; Carnbrea and Tincroft Mines, Ltd., 1.5 per cent. of black tin. Once underground, the work of mining can be carried on the entire year without much difficulty. The season for milling the ore is necessarily very short—possibly five months at the most.

Table IV. gives the annual output of tin in various countries of the world during 1905 and 1906.<sup>6</sup> It is to be noted that the United States is conspicuous by its absence.

TABLE IV.—*The Principal Tin Supplies of the World, During 1905 and 1906. (In Tons of 2,240 lb.)*

	1905.	1906.
English Productions.....	4,468	4,920
Straits to Europe and America.....	56,847	57,138
Straits to India and China.....	1,700	1,300
Australia to Europe and America.....	5,028	6,888
Banka sales in Holland.....	9,960	9,300
Billiton sales in Java and Holland.....	2,715	1,950
Bolivian arrivals on Continent.....	12,500	14,700
Bolivian arrivals in England.....		
Totals in long tons.....	93,218	96,196
Totals in metric tons.....	94,709	97,735

It is to be hoped that the tin-deposits in this section may prove to be of commercial importance. It must be said, however, that much time and money will be required to put the industry in Alaska on a paying basis. At the present time, operations are in the prospecting stage, and it is merely conjecture to say what will be the outcome.

#### ACKNOWLEDGMENTS.

In presenting this paper, I wish to express my gratitude to Prof. Jas. F. Kemp, and Mr. E. G. Spilsbury for valuable suggestions and criticisms. I should also mention specially the paper of Mr. F. L. Hess, entitled *The York Tin Region*,<sup>7</sup> in

<sup>5</sup> *Mineral Industry*, vol. xiv., p. 538 to 546 (1905).

<sup>6</sup> *Mineral Industry*, vol. xv., p. 718 (1906).

<sup>7</sup> *Bulletin No. 284, United States Geological Survey*, pp. 145 to 157 (1905).

which are described some things that I have independently observed.

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## Coal-Briquetting in the United States.\*

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\* Published by permission of the Director of the U. S. Geological Survey.

(Toronto Meeting, July, 1907.)

NOTE.—The material from which this paper has been prepared was collected for the *U. S. Geological Survey Bulletin*, Contributions to Economic Geology, 1906, and appears also, though in somewhat more extended form without illustrations, in that publication.

ALTHOUGH the briquetting of coals and lignites has been carried on for many years in Europe, and has reached a particularly high state of development in France, Belgium, and Germany, it has made comparatively little progress in the United States. The causes for the backwardness of the United States in this regard are several, and first among them has been the abundant supply of cheap raw fuel with which the manufactured article has to compete. With our millions of acres of coal-productive territory, from which the product can in most cases be cheaply extracted, it has appeared in many districts more economical to waste the slack or culm, which constitutes a considerable percentage of the product, than to attempt to save it at the additional expense required for briquetting. It is for this reason that the view in all sections of the anthracite-region of Pennsylvania is marred by the unsightly culm-banks which encumber the ground, and that in some of the bituminous-districts one sees huge piles of unmarketable slack allowed to burn up in order to get rid of them. When the coal is of a coking quality, or when the slack can be used for steaming-purposes, these losses are not sustained, but many thousands of tons of what might be converted into usable fuel have been wasted every year simply because of the increased expense involved in its preparation.

The rational development of the briquetting-industry has also been retarded by the attempts to exploit patented or secret processes for which all kinds of extravagant claims have been made, but which have almost invariably proved expensive and unprofitable, and the investment of capital in enterprises of this character has been discouraged accordingly. The Patent Office records teem with patents issued on all sorts of inventions relating to binders, many of which are as fanciful as the idea of perpetual motion.

Another reason for the failure to build up a briquetting-industry in the anthracite-region of Pennsylvania, where the best opportunity for its development is offered, has been the opposition shown by some of the operators to the introduction of a manufactured domestic fuel which would come into competition with the prepared sizes of anthracite. And such an opposition is natural. The competition of bituminous coal has almost entirely shut out anthracite as a steam-fuel. The use of coke has supplanted the use of anthracite for iron-making, and the use, for domestic purposes, of coke and gas made from bituminous coal is growing. Owing to the greater depths to which the mining of anthracite is being carried, the thinner and less favorably located beds which are being worked, and to the increasing tendency in labor-cost, the mining and preparing of anthracite are constantly becoming more expensive on one hand, while competition is becoming more keen on the other. A certain rate of production must be kept up for the protection of the properties themselves, and when all these conditions are considered, the unfavorable attitude on the part of the operators toward further competition is at least realizable.

Still another reason which has been assigned, rightly or wrongly, for our halting progress in fuel-briquetting has been the lack of assurance of a regular supply of coal-tar pitch at reasonably low prices. Out of the many, and sometimes costly, attempts that have marked the incubating period of briquetting development has grown the knowledge that coal-tar pitch must be relied upon to supply, in the eastern States at least, all, or the greater part, of the binding-material. In California, Arizona, and other parts of the far West, asphaltic pitch, the residual product from the refining of the heavy asphalt-base petroleum of that region, has been, and is now, successfully

used in recently constructed briquetting-plants. But in the East, coal-tar pitch is the base of the economically successful cementing-material. The extended investigations carried on at the U. S. Geological Survey coal-testing plant at St. Louis bear out this statement.<sup>1</sup> These investigations included experiments with all kinds of organic and inorganic binders, embracing, besides coal-tar pitch, such materials as rosin, sugar-house refuse, molasses, acid-sludge, quick-lime, and various mixtures. The results show that coal-tar and asphaltic pitch are the only really successful binders. Any materials used with them must possess above all others the essential virtue of cheapness.

But while it is claimed that the briquetting-industry has been held back by the lack of assurance of a steady supply of coal-tar pitch, it also happens that one of the reasons assigned for the comparatively slow development of the by-product coking-ovens in the United States in the last few years is the lack of a profitable demand for coal-tar, one of the principal by-products of the retort coke-ovens. It is well known that the demand for creosoting-oils to be used for the preservation of ties, bridge-timbers, etc., by the railroad-companies is far beyond the present domestic production of that coal-tar product, and the statistics compiled by the Bureau of Statistics, Department of Commerce and Labor, show that our imports of the chemical products of coal-tar exceed \$10,000,000 in value yearly. To the ordinary observer it would appear that the conditions here presented afford an opportunity for the organization of a community of interests which would prove profitable to the projectors and beneficial to the general public. The constantly increasing expense involved in the mining and preparation of anthracite coal is making that commodity slowly but surely more and more of a luxury, and manufactured fuel which will take the place of anthracite for domestic use, particularly among consumers of moderate means, appears to be needed. This is especially true in the northeastern section of the United States.

Two of the briquetting-plants recently constructed, and which are discussed in more detail in the following pages, in-

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<sup>1</sup> *United States Geological Survey Bulletins* Nos. 261 and 290, and *Professional Paper* No. 48.



dicate somewhat of a "getting together" of the coal-tar producing and the briquetting-interests. These are the plants of the United Gas Improvement Co., at Point Breeze, Philadelphia, and of the Semet-Solvay Co., at Del Ray, Mich. Both companies are producers of coal-tar, and the plants have been constructed for the purpose of briquetting mixtures of anthracite-culm and coke-breeze.

It appears now, moreover, that the period of failure and discouragement has passed, and that the manufacture and use of briquetted fuel is being placed upon a substantial footing. The first successful plant in the United States of which I have any definite knowledge was one built at Stockton, Cal., a few years ago by the San Francisco & San Joaquin Coal Co. This plant, unfortunately, was entirely destroyed by fire in 1905, and the plans for its reconstruction, this time at San Francisco, were interrupted by the earthquake and fire which destroyed a large portion of that city in April, 1906.

During the past two years a number of briquetting-plants have been constructed, and as complete descriptions of them as it has been possible to obtain are given in the subsequent pages. Some of them have been put in operation since Jan. 1, 1907.

#### NEW YORK, N. Y.

*New Jersey Briquetting Co.*—During 1904 and 1905 the New Jersey Briquetting Co. of New York constructed at the foot of Washington Street, in Brooklyn, a plant for exploiting the briquetting-process of the Zwoyer Fuel Co. This plant was intended to be operated in connection with a coal-yard on Adams Street, but during the construction of the piers and anchorages for the new Manhattan bridge, the company was prohibited from operating the tramway from the coal-yard to the plant. This naturally interfered with the operations of the plant, and as extensive storage-capacity, either for raw material or for the product, had not been provided for, the work already done has been accomplished under much disadvantage. The prohibition put upon the tramway, and the lack of dock-facilities for loading and unloading material, have crippled the plant to such an extent that what was supposed to be an excellent location has turned out to be an unfortunate one, and the present methods of receiving and handling the material make the

operations too expensive for successful competition of the briquettes with raw fuel. As a result of these unfortunate conditions it is proposed to remove the plant to a site better adapted for the receiving, storage, and shipment of material. The officials of both the New Jersey Briquetting Co. and the Zwoyer Fuel Co. are entirely satisfied with the experimental results, and are confident of making the enterprise a commercial success.

A description of the plant in Brooklyn has already been published,<sup>2</sup> and the following notes are partly abstracted therefrom and partly furnished by Mr. Virgil H. Hewes, Treasurer of the Zwoyer Fuel Co.

Prior to the construction of the plant in Brooklyn, the Zwoyer Fuel Co. had built a small experimental plant in Jersey City, N. J., but while this was of sufficient capacity for this purpose, it was not large enough to be operated as a commercial undertaking, and was abandoned.

It may be stated here that after a considerable expenditure of time and money in experimenting with different kinds of binders, coal-tar pitch was decided upon as best suited to the work, a decision which has been generally reached in the eastern States, as asphaltic pitch has been adopted in the far West, where that article is cheaply obtained. During the progress of the experimental work, about 200 tons of briquettes were made with a binder composed of 6.25 per cent. of rosin and oil, 1.5 per cent. of flour and water, and from 6 to 10 per cent. of bituminous coal, the body of the briquette being anthracite-dust. About 900 tons of briquettes were made, using from 5 to 7 per cent. of rosin and oil and 10 per cent. of bituminous coal; 400 tons were made with from 5 to 7 per cent. of wood-pitch and 10 per cent. of bituminous coal, and 1,500 tons were made with from 6 to 7 per cent. of coal-tar pitch alone. In applying the binder during the last three experiments an atomizer was used.

The plant in Brooklyn has a capacity of 10 tons per hour, and was built for the purposes of demonstration. During the winter and spring of 1905-6 about 3,000 tons of anthracite-briquettes were made and sold. The price received was \$5 per

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<sup>2</sup> *Iron Age*, vol. lxxvii., pp. 1330 to 1333 (1906).

ton of 2,000 lb. at the plant, \$5.50 per ton delivered, and \$6.60 per ton in bags of 100 lb. each. These prices were \$0.50 below the prices of the domestic sizes of anthracite.

A plan of the building,<sup>3</sup> which is nearly triangular in outline, is shown in Fig. 1, which gives also the general arrangement of the machinery.

The anthracite-dust is received on Washington Street at the end of a screw-conveyor, which carries it to the foot of an elevator, where it is lifted to the top of the plant and is then spouted to a screen located over the dust-bin. The coarser material is spouted either to the boiler-room or to an over-size bin in the rear of the dust-bin, and from here fed into a crusher and then passes to the foot of the dust-elevator, where it is again carried to the screen. The dust is drawn from the dust-bin by a conveyor driven from a variable-speed countershaft, and is fed to the 16-in. by 36-in. roll-crusher. It then passes to an elevator which carries it to the mixers. After passing through mixers Nos. 1 to 6 it is carried to the second floor, when it falls into the press-hopper.

From the press the briquettes are carried by a belt-conveyor to the baking-oven (when smokeless briquettes are wanted), and are then elevated to and distributed upon the cooling-table, which is located on the second floor. After cooling, the briquettes are run into chutes and loaded into wagons for delivering, or are stored. In New York the briquettes sold readily when not baked.

On one side of the dust-bin a soft-coal bin was built from which soft coal was fed into a 19-in. by 4-in. roll-crusher and passed to the same elevator which carries the dust to the mixers. Development has shown that it is not necessary to use the soft coal with anthracite-dust. However, this bin is used when experimental runs are made requiring the mixing of different materials with the dust.

The Binder.—Coal-tar pitch, used as a binder, is received on the Plymouth Street side of the building. It is hoisted to the second floor by means of a barrel-hoist, where the staves are removed and the pitch is thrown into the binder melting-tank (the tank holding about 15 tons of pitch), and pumped by

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<sup>3</sup> *Iron Age*, vol. lxxvii., p. 1330 (1906).

means of a rotary-pump into the storage or hot binder-tank, where it is kept heated.

The Mixers.—Fig. 2 shows a plan and elevation with the relative position of the connecting mixers and heat-flues, and Fig. 3 shows a section of a typical mixer unit. The number of units necessary in a mixer depends upon the material to be briquetted and the condition in which it is received. At this plant six were used, and have proved well adapted to the handling of coal, hard and soft, wet or dry, coke-breeze, and even iron-concentrates.

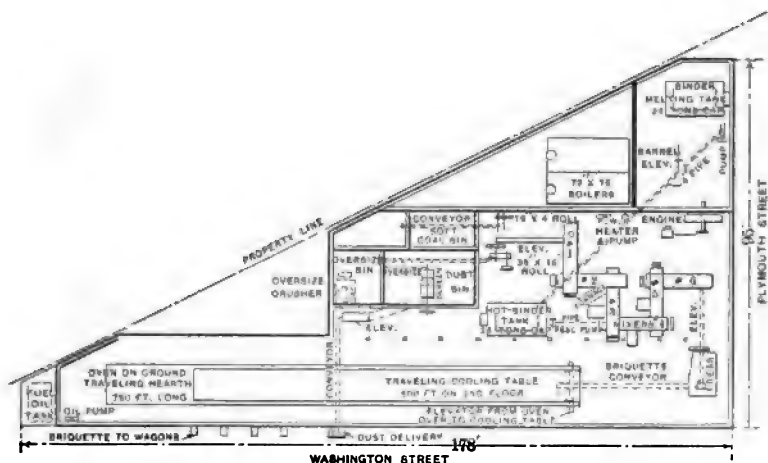


FIG. 1.—PLAN OF THE PLANT OF THE NEW JERSEY BRIQUETTING CO., BROOKLYN, N. Y.

The dust enters No. 1 mixer at *C*, Fig. 2, and is carried through mixers Nos. 1 to 6 in the direction indicated by the arrows to a point, *O*, mixer No. 6, and then by conveyor to the press. In passing through mixers Nos. 1 and 2 the dust is heated by the furnaces,  $F_1$  and  $F_2$ , to drive off all the moisture. The coal-tar pitch, being previously heated, is pumped from the storage-tank by a small rotary-pump driven from a variable-speed countershaft, which regulates the percentage of pitch used.

The pitch is delivered to the mixer No. 3 at the point, *T*, Fig. 2, where it is atomized by means of a steam-jet.

The above apparatus and process are patented.

The Press.—The roll type of press, shown in Fig. 4, is used, the rolls being built up of disks which are milled to form the pockets and are then assembled and bolted together on the shaft. This method, as well as the design of the briquettes, is patented. Two sizes of briquettes are made,  $1\frac{1}{2}$  in. by  $1\frac{1}{2}$

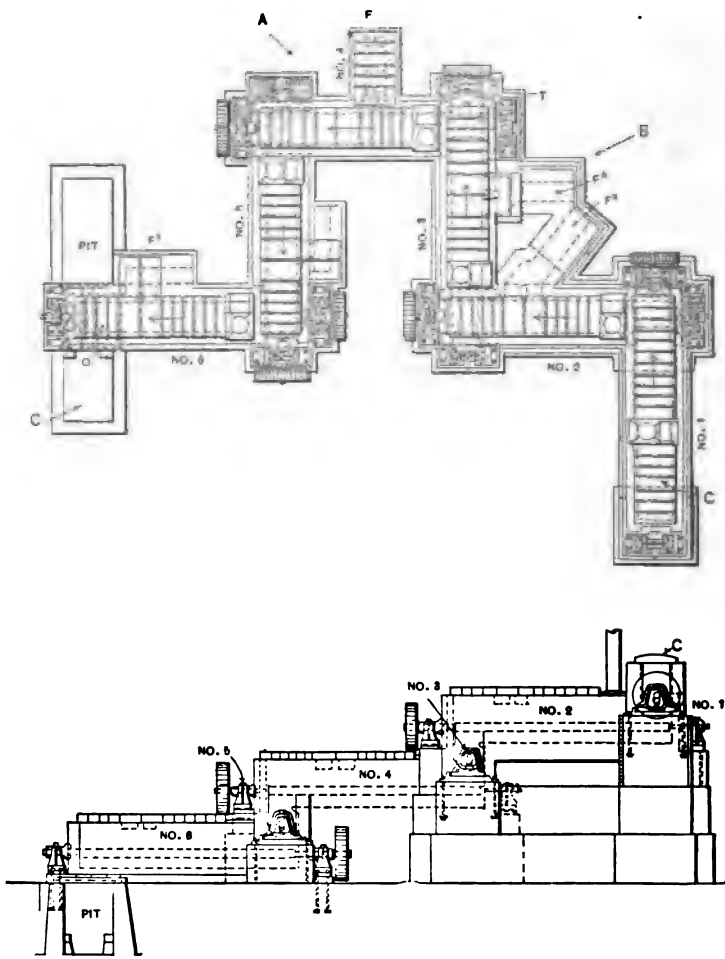


FIG. 2.—PLAN AND ELEVATION OF THE MIXERS.

in. by  $1\frac{1}{2}$  in. and  $2\frac{1}{2}$  in. by  $2\frac{1}{2}$  in. by  $1\frac{1}{2}$  in. The briquettes are square "pillow" or "pin-cushion" shape. The smaller ones weigh 2 oz. and the larger 3.3 oz.

Cooling-Table.—The cooling-table consists of three endless belts composed of steel plates carried at their ends by sprocket-

chains, the belts being placed one over the other and carrying the briquettes back and forth six times over a distance of 84 ft., making a total travel of 504 ft. The briquettes are then run into bins or loaded into wagons.

*Staten Island Plant.*—The Briquette Coal Co., J. P. Egbert, Manager, No. 2 Stone Street, New York, N. Y., has just completed the construction of a briquetting-plant at Stapleton, on Staten Island. This plant is constructed for the purpose of using anthracite-dust with coal-tar pitch as the basis of the binding-material. The anthracite-dust is used as delivered. The plant does not possess any novelties in its design, except that there are two presses of radically different types. One of these is of German manufacture, built at the works of

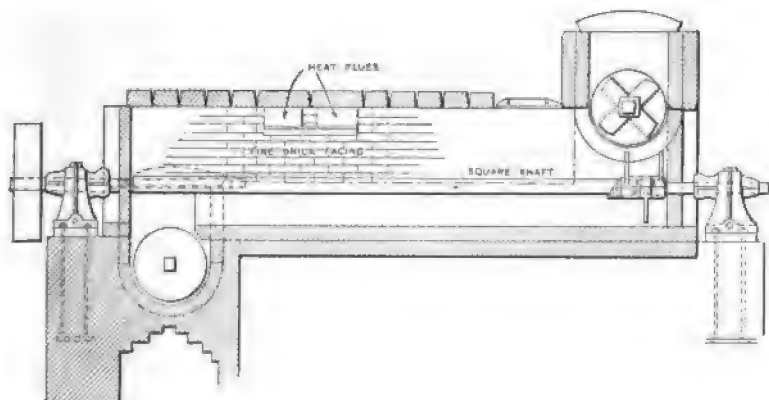


FIG. 3.—SECTION OF A TYPICAL MIXER.

Schüchtermann & Kremer, of Dortmund. This press is of the plunger type, in which the manner of feed, compression and ejection is similar to the Johnson (English) machine used at the U. S. Geological Survey testing-plant at St. Louis, except that the disk containing the compressing-molds is set and revolves horizontally instead of vertically. The briquette is paralleloiped in shape with the end edges rounded. Its dimensions are 4.75 by 2.25 by 2.5 in. Each briquette weighs about 1.5 lb. and has a specific gravity of about 1.24.

The second press is what is generally classed as the Belgian type, similar to the one described as the "American" machine used at the U. S. Geological Survey testing-plant. This particular machine was made at the works of H. Stevens, at Char-

leroi, Belgium. The product is of the eggette pattern, which is more desirable for domestic use than the larger briquette. The eggettes weigh about 5 oz., and have a specific gravity of 1.37. The manager of the company, Mr. Egbert, extended to me every courtesy possible, but unfortunately was not able to furnish any complete drawings or other illustrations, the plant having been constructed without them. The total capacity of this plant with both presses in operation is 120 tons of briquettes per day of 10 hr. The German machine will turn out 4.5 tons, and the Belgian machine 7.5 tons per hour.

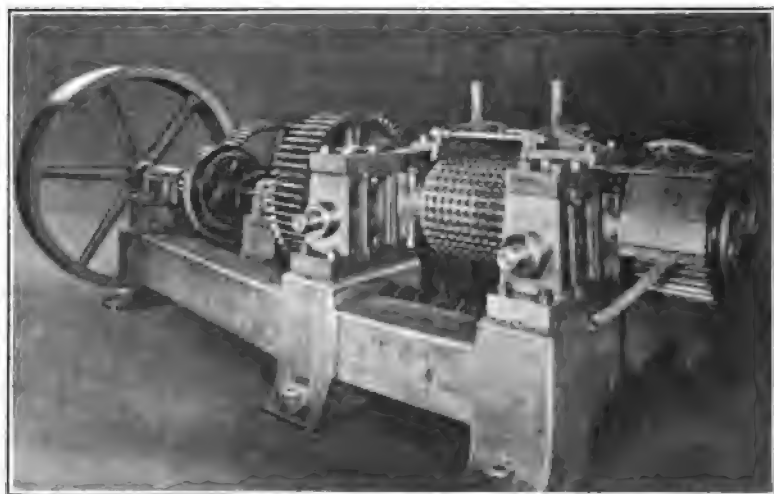


FIG. 4.—BRIQUETTING-PRESS OF THE NEW JERSEY BRIQUETTING CO.

*South Brooklyn Plant.*—Another plant, which has just been completed as this report is written, in that of the National Fuel Briquette Machinery Co., of New York, N. Y. This plant is located at the foot of Court and Smith Streets, Brooklyn, and close to the Gowanus canal, by which the materials to be used can be brought in barges and discharged at a minimum of expense. While intended to be operated upon a commercial basis, it may be considered rather as a demonstrating-plant. It is intended for the use of anthracite-dust with coal-tar pitch as a binder. The press is of the Belgian type, producing eggettes or “boulets,” somewhat smaller than an ordinary hen’s egg, and made exclusively for domestic use. The machinery used in this plant was patented in this country<sup>4</sup> by

<sup>4</sup> U. S. Patent No. 799,149, Sept. 12, 1905.

Hubert J. Debauche, Gilly, Belgium, and assigned to Mr. Robert Devillers, with whom I visited the plant, and to whom acknowledgments are made for courtesies extended. The eggettes produced by this plant are much smaller than those ordinarily made, weighing only about 1.5 oz. each, and having a specific gravity of 1.3.

*North American Coal Briquette Co.*—This company, with office at 177 Broadway, New York, N. Y., has been incorporated for the purpose of exploiting the Forst briquetting-process, which comprises chiefly the material to be used as a binder, part of which, though kept secret, consists principally of coal-tar pitch. The merit claimed for the secret ingredients of the binder is a great economy in the quantity of binder used for the manufacture of superior briquettes. The company has negotiated for the purchase of a Duprey (French) machine, and has sent 10 tons of anthracite coal and one ton of binder to Paris for the purpose of demonstrating the claims made for the process controlled by the company.

*The Mashek Briquetting-Process.*—The briquetting-machine designed by Mr. G. J. Mashek (now with the Traylor Engineering Co., New York, N. Y.) has been described in detail by him.<sup>5</sup> The process was designed for the purpose of overcoming the objections to the use of briquetting-machinery which had developed, principally through the failure of certain foreign-made machines to meet the requirements of the American trade. When starting on the development of his plans, in 1903, the general type of machinery in use in Europe was that making the large rectangular briquettes, weighing from 7 to 20 lb. each, and these proved unsuitable to American use. In designing his press Mr. Mashek adopted the Belgian idea of molds contained in the peripheries of two tangential wheels, but instead of the eggette pattern, developed one which minimizes the blank spaces between the molds and produces a briquette of pillow or pin-cushion shape.

A view of the Mashek press, Fig. 5, shows the molds on the periphery of the cylinders, and Fig. 6 is another view of the press.

The Traylor Engineering Co. has recently built for Mr. E. B. Arnold a Mashek press, which has been installed at the

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<sup>5</sup> *Iron Age*, vol. lxxvii., pp. 1330 to 1333 (1906).



foot of West 47th St., New York, N. Y. The building in which this is located was designed and erected for, and originally equipped with, a different type of machinery, but the briquettes made proved to be of a shape and character unsuited to the trade, and the cost of manufacture was also too high to enable the briquettes to compete with natural coal. When it was decided to substitute a Mashek press for the old one, it was also deemed advisable to use the same building, which is

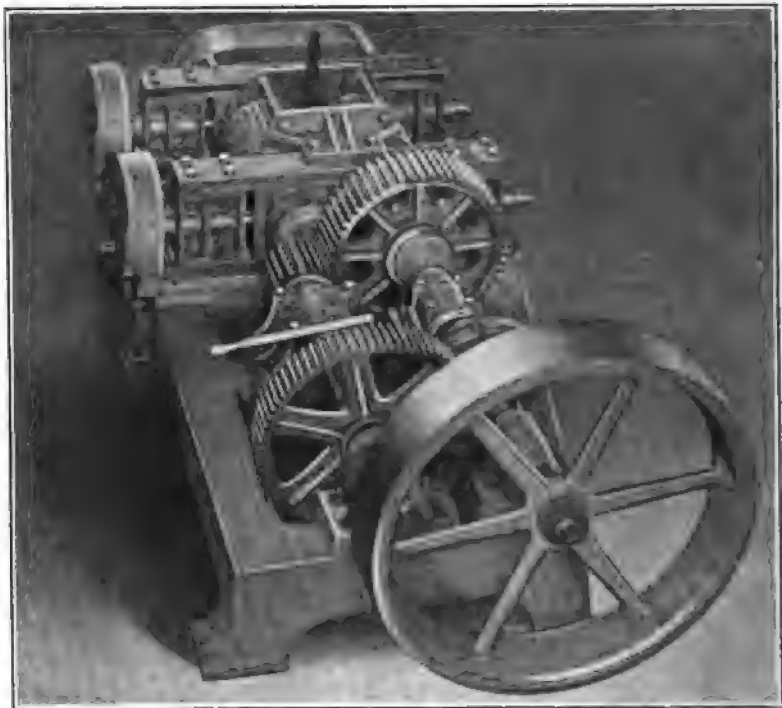


FIG. 5.—MASHEK BRIQUETTING-PRESS, SHOWING MOLDS ON PERIPHERY OF CYLINDERS.

a substantial one, and also, as far as possible, the old machinery (such as elevators, shafting, power-plant, etc.), which was practically new and in good order, but which did not permit of the most desirable arrangement.

The new press installed has a capacity of about 14 tons per hr. of 2-oz. briquettes, but on account of using so much of the old equipment it is impossible to handle sufficient material to keep the machinery running at its full capacity, and it is now

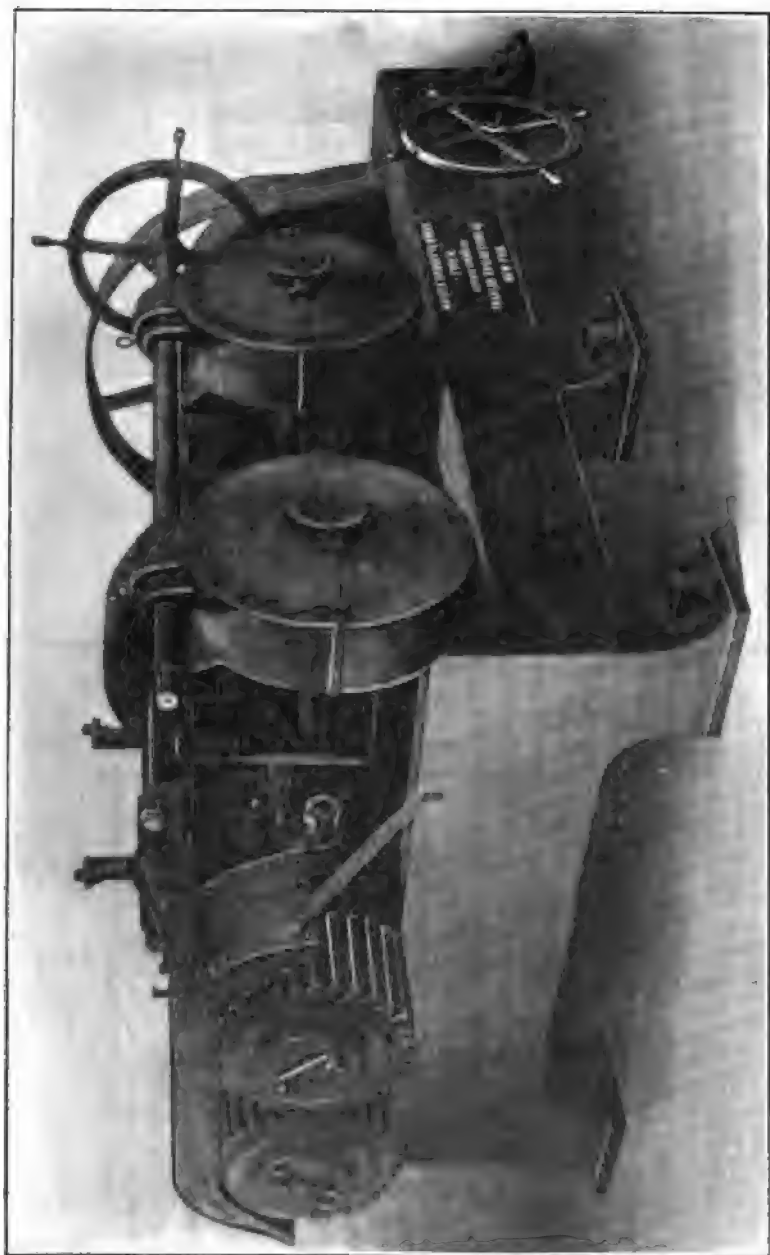


FIG. 6.—MASHEK BRIQUETTING-PRESS COMPLETE.

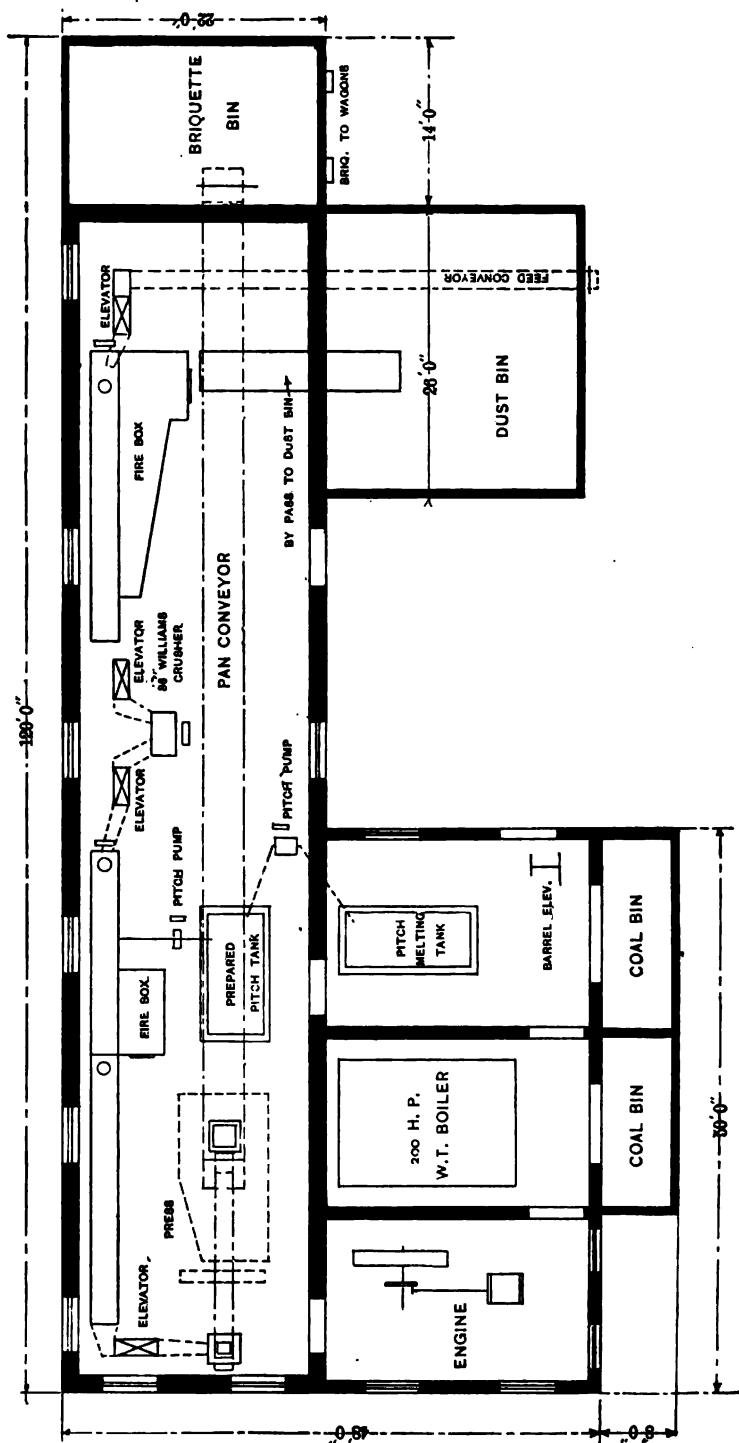


FIG. 7.—PLANT OF MASHEK PROCESS. (Plan.)

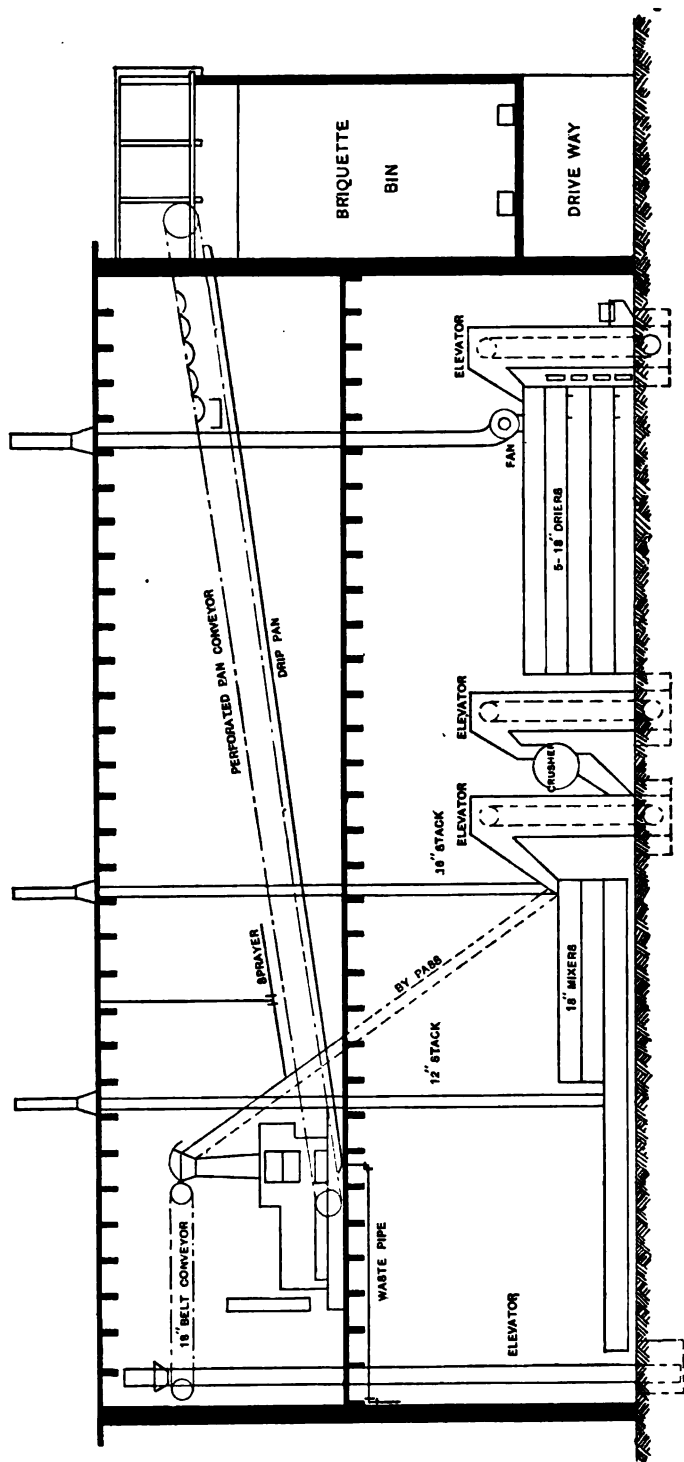


FIG. 8.—PLANT OF MASHEK PROCESS. (Elevation.)

operated at the rate of about 10 tons per hr. The cost of labor, fixed charges and other expense being the same, the cost of production is slightly higher per ton of briquettes than would have been the case if the plant was operated up to its maximum capacity. The size of the briquettes to be made has been determined by putting them on the market and selling them for domestic purposes, starting with 1-oz. briquettes and running up to 3-oz. It was found that the majority of users preferred a 2-oz. size, which corresponds with the stove-coal size of anthracite. The weight, of course, will vary with the nature of the dust from which the briquette is made, and it has been found that in using coke-breeze a 2.5-oz. briquette is most desirable, and about a 3-oz. if made of soft coal and lignite. The press is so designed that a change of the mold-shells can be made in about 2 hours.

The plan and elevation of the Arnold plant are given in Figs. 7 and 8. The arrangement of the machinery is shown in Fig. 8. The anthracite-dust is elevated to the dust-bin, from which it is drawn by a feed-conveyor so arranged that the feed is constant and can be regulated as desired. This conveyor discharges into a chain-elevator, which in turn discharges into a battery of five 18-in. rotary driers and heaters. These are super-imposed one above the other and all bricked in. The material is conveyed through these driers by means of screw-mixers until it passes into the following elevator.

On the side of these driers is constructed a furnace, the products of combustion from which are distributed into the driers through openings into the different units, so that no unit gets heat sufficient either to char the dust or to burn out the iron-work of the paddle-conveyor. An exhaust-fan draws off the products of combustion and the moisture. The temperature of the discharge-gases and moisture from the drier rarely exceeds 212° F. After the material passes out of the drier into the elevator it is elevated and dropped into a 36-in. Williams pulverizer, where the larger pieces are crushed, so that everything passes through about a 12-mesh screen. From the pulverizer the material is again elevated to another series of mixers and coolers similar in construction to the driers. The anthracite-dust at this point has a temperature of about 300° F. The coal-tar pitch is here introduced by means of a

pitch-pump so arranged as to deliver a definite quantity of pitch, as desired. Alongside of this last battery of mixers is a small furnace which heats the two upper mixers, maintaining an even temperature of the mixture and not allowing it to stiffen or set. From the last mixer the material drops to an elevator which takes it up to the second floor and discharges it on to an 18-in. belt-conveyor, which delivers the material over the press and into the hopper. The press is run continually, discharging the briquettes into a perforated-pan conveyor, which conveys them to the briquette-bin. The briquettes while in this conveyor are subjected to a heavy spray of water in order to cool and clean them.

The coal-tar pitch used in this plant is of the ordinary roofing-hardness; it is delivered by lighter on an adjacent dock and carted to the pitch-melting house, where it is melted in a tank 6 ft. wide, 12 ft. long, and 8 ft. deep.

This pitch-melting tank will hold about 22 tons of pitch, which requires in the neighborhood of 20 hr. to melt. After the pitch is melted and brought up to the proper temperature for use it is drawn off by means of a large pitch-pump into the "prepared-pitch tank," from which it is pumped into the mixers.

This plant requires about 125 hp. to turn out 10 tons per hr. It has been in operation about two months and is said to be giving excellent results. The product is used almost entirely for domestic purposes, and commands the same price as the best grade of prepared anthracite coal in the New York market. A large portion of the output is put up in paper bags and handled by grocers and small coal dealers the same as charcoal or crushed coke. The bag trade caters to the poor people who do not buy in large quantities, and is a considerably cleaner method of distributing the product than that formerly used.

Out of the briquette-bin the briquettes are handled the same as ordinary coal, and experience has shown in this and other plants that abrasion or breakage averages about 3 per cent., which is slightly less than with ordinary prepared coal.

The cost of manufacture is as follows:

*Pitch:*

Using 6 per cent. of pitch at \$10 per ton, . . . . .	\$0.60
Deducting increased weight of product due to 6 per cent. of pitch, and calculating product at \$5 per ton, . . . . .	0.30
Net cost of pitch, . . . . .	<u>\$0.30</u>

*Fuel:*

For boiler, broken coal and screenings, broken briquettes, 4 tons per day of 10 hr., at \$2.50 per ton, . . . . .	\$10.00
Per ton of briquettes, . . . . .	0.10
For heaters, driers and pitch-melting, 3 tons at \$2.50 per ton= per ton of briquettes, . . . . .	0.075

*Labor:*

	<i>Per Day.</i>
1 foreman, . . . . .	\$5.00
2 pitch-melters, . . . . .	3.50
1 dust-bin man, . . . . .	1.75
1 engineer, . . . . .	3.50
1 man on second floor, . . . . .	1.75
1 man on ground floor, . . . . .	1.75
1 night watchman, . . . . .	1.75
1 oiler, . . . . .	1.75
	<u>\$20.75</u>
Per ton of briquettes, . . . . .	0.21

*Miscellaneous:*

Wear and tear, per ton of briquettes, . . . . .	0.10
Lubricating oil, per ton of briquettes, . . . . .	0.01
Insurance, . . . . .	0.005
Interest on capital invested, \$40,000, at 6 per cent., . . . . .	0.10
Office expense, telephone, stenographer and stationery, \$2,000 per annum, . . . . .	0.09
	<u>\$0.99</u>
Anthracite-dust at \$1.40 per long ton = per net ton of briquettes, . . . . .	1.25
Total cost of briquetting, . . . . .	<u>\$2.24</u>
Re-briquetting 3 per cent. of breakage and abrasion, charging it back to plant as dust, per ton of briquettes, . . . . .	0.06
Net cost per ton of briquettes, . . . . .	<u>\$2.30</u>
Wholesale selling-price in bin, . . . . .	4.80
Net profit per short ton, . . . . .	<u>\$2.50</u>

## PENNSYLVANIA.

It might be supposed that the briquetting-industry would have its greatest development in or near the anthracite-region of Pennsylvania, where a plentiful supply of raw material is available in the great culm-banks created through the many years of mining, and in the still large amount of fine coal pro-

duced at the breakers for which no profitable market has yet been found. Up to the present time, however, there are but two briquetting-plants in operation in the State, one at Point Breeze, in the city of Philadelphia, and the other at Dickson, a few miles from Scranton. Both of these were put in operation in 1906. The plant at Dickson is in the immediate vicinity of the mine of that name, operated by the Delaware, Lackawanna & Western Railroad Co., and uses the fine coal or screenings, below marketable sizes, coming from the washery operated in connection with the mine. The owner of this plant, the Scranton Anthracite Briquette Co., withholds information relative to the details of its operations. I have been informed, however, by one of the officials of the company that the base of the binding-material used is coal-tar pitch, and that the plant is producing at the present time—April, 1907—from 300 to 325 long tons of briquettes per day. It is the intention to double this output by running the plant night and day. The briquettes are of the oval or eggette shape, the press being of the Belgian type, and similar to the "American" machine used at the testing-plant of the U. S. Geological Survey at St. Louis during the exposition period.<sup>6</sup> The entire product is taken by the Delaware, Lackawanna & Western Railroad Co. for use, principally, on its locomotives.

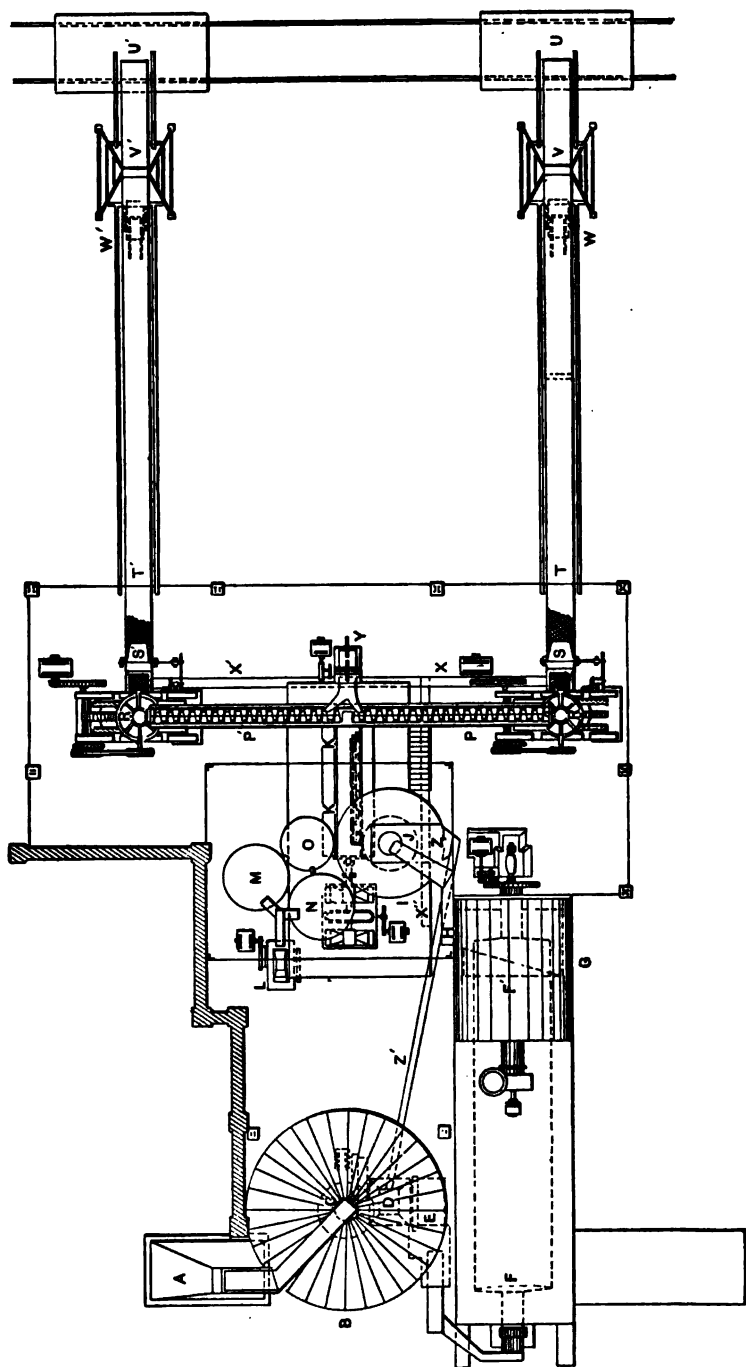
The other plant, at Point Breeze, is owned and operated by the United Gas Improvement Co., and was constructed for the purpose of utilizing the coke-breeze produced at the gas-houses of the company, and in this case, as in the case of the plant at Dickson, the product is not placed upon the market but is used by the company in its retorts for the manufacture of water-gas. I am indebted to Mr. W. H. Gartley, Engineer of Works of the United Gas Improvement Co., for the following detailed description of the plant, and for the accompanying illustrations, Figs. 9 and 10.

It has been found advantageous to use a mixture of anthracite-culm and coke-breeze, with from 5 to 7 per cent. of coal-tar pitch as a binder. The proportions of culm and coke used are variable, according to the quantity of material on hand. At the time I visited the plant—November, 1906—three parts

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<sup>6</sup> *United States Geological Survey Bulletin No. 261, and Professional Paper No. 48.*





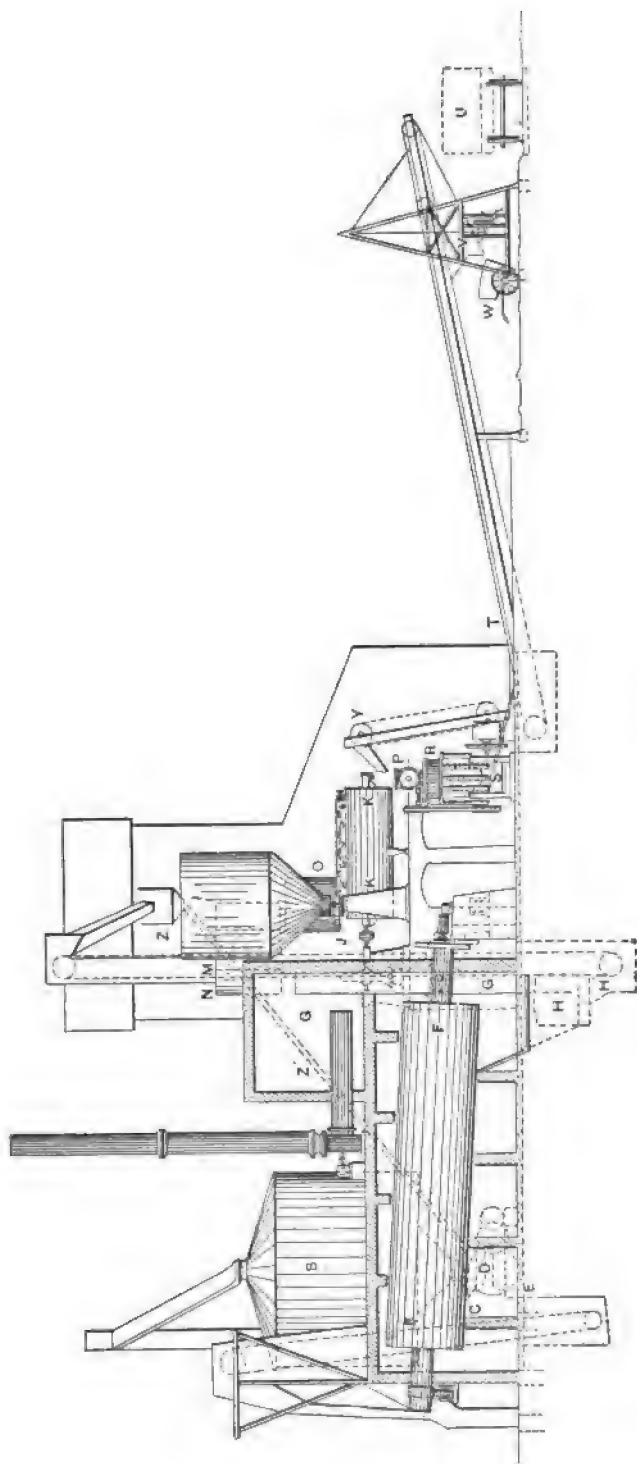


FIG 10.—BRIQUETTE-PLANT OF THE UNITED GAS IMPROVEMENT CO., PHILADELPHIA, PA. (Elevation.)

of culm to two parts of coke were being used. The press is of the Belgian type, producing eggettes about the size of a goose-egg. The rated capacity of the plant is 10 tons of eggettes per hr. It has been in operation regularly, producing 90 tons per 9-hr. day, except when it has been shut down for repairs and changes. Figs. 8 and 9 show the arrangement of the plant.

The breeze or screenings from the coke-screen (not shown on the diagram) of the coal-gas plant fall into a pocket or hopper, *A*. Into this pocket is also dumped the culm. The contents are raised by an elevator into the storage-tank, *B*, discharging through the funnel-shaped bottom on to the automatic feed-table, *C*, by which a measured stream of the material is continuously poured, part into the crusher, *D*, and part directly into the hopper, *E*, below the crusher. The material is then elevated and discharged into the drier, *F*, *F'*. The dried material, together with the dust from the dust-chamber, *G*, *G'*, of the drier is discharged into the hopper, *H*, *H'*, elevated and discharged through a shaking-screen into the storage-tank, *I*, located above the mixer. All material not fine enough to pass through the screen, *Z*, is returned by a spout, *Z'*, to the crusher, *D*. The dried material in tank, *I*, is discharged through the funnel-shaped bottom on to the automatic feed-table, *J*, by which a measured stream is continuously poured into the mixer, *K*, *K'*. Into the feed-end, *K*, of the mixer is also pouring a continuous stream of liquid-pitch through a positive measuring-faucet (not shown), driven from the driving-mechanism of the mixer through a variable-speed device (not shown). The pitch is brought into the building as broken from the pitch-bays of the tar-distillery, fed into the pitch-cracker, *L*, elevated and discharged into the large steam-heated pitch-storage tanks, *M*, *N*, where it is melted. From these tanks the melted pitch is drawn, as required, into the smaller steam-heated tank, *O*, to which the faucet, previously mentioned, is attached.

The warm, dry, and continuously measured crushed breeze and culm, together with the melted and continuously measured pitch, are thoroughly mixed and kneaded in the steam-jacketed mixer, *K*, *K'*. The mixed mass is discharged from the mixer, divided (device not shown) into two streams and carried by two mixing-conveyors, *P*, *P'*, allowing time for cooling and

setting, into the feed-pans of the two presses, *R, R'*, purchased in France. From the feed-pans the material is fed to the presses, which press out the eggettes and discharge them on to the shaking-screens, *S, S'*, below, which screen them from the waste and fines. They are then discharged on to the woven-wire belt-conveyer, *T, T'*, giving the eggettes time to cool and set, and conveyed either to the cars, *U, U'* or to the hoppers, *V, V'*, from which the buggies, *W, W'* for the generator-house are filled.

The waste and fines from the shaking-screens, *S, S'*, under the presses, are conveyed by conveyors, *X, X'*, to the hopper, *H'*, at the discharge of the drier.

Screenings from the eggettes taken from the storage-piles are returned by an elevator, *Y*, to the discharge of the mixer and assist in the cooling of the heated mixture.

#### CALIFORNIA.

The manufacture of briquettes has shown more actual progress in California than in any other State of the Union. This has been brought about through the efforts to improve the fuel-quality of the rather low-grade California lignites, and has been encouraged by the high prices of the better grades of bituminous coal or anthracite brought into the State from Washington, the Rocky mountains, and eastern States, or imported from British Columbia, England, Australia, and Japan. It has also been encouraged by the cheap asphaltic pitch obtained from California petroleum, which not only serves excellently as a binder but adds to the calorific value of the briquetted fuel.

The first plant to be put into successful operation in California was one built at Stockton by the San Francisco & San Joaquin Coal Co. The plant was completed in 1901, and when running at full capacity could produce 125 tons of briquettes per day. The fuel used was lignite from the Tesla mines, in Alameda county. The plant was, unfortunately, entirely destroyed by fire in 1905 and has not been rebuilt. It is stated that the plans of the company were to rebuild the plant at San Francisco, but these were upset by the earthquake and fire which destroyed a large part of that city in April, 1906. A complete description of the Stockton plant by the designer of

the presses, Mr. Robert Schorr, of San Francisco, has been published.<sup>7</sup> The briquettes produced at this plant were round, convex lenses or "boulets," which weighed from 6 to 8 ounces.

The Western Fuel Co., of Oakland, completed, early in 1905, a briquetting-plant also designed by Mr. Schorr.<sup>8</sup> In mechanical construction this plant differs materially from the one destroyed by fire at Stockton. The shape of the briquettes is cubical instead of "boulet." The advantage claimed for the cubical shape is that the briquettes ignite more readily, though it is admitted that in handling the same mechanically there is more waste.

The capacity of this plant is 480 briquettes per min., or 8.5 tons per hr. The fuel used is coal-yard screenings from lignites, anthracite, and sub-bituminous coals, with about 7.5 per cent. of asphaltic pitch. This pitch is obtained by the distillation of California crude petroleum. The temperature of the still, for the production of the proper grade of pitch, is about 600° F. Some difficulty has been experienced in securing the right quality of pitch on account of the tendency of the refineries to "rush the stills," their aim being the securing of refined oils rather than pitch. An excellent grade of asphaltic pitch is obtained by keeping the stills at a temperature of 500° F., using a vacuum to force the distillation. Grade "D," the quality best adapted for the purpose, is fairly hard up to 60° F., but begins to soften above that point. It becomes liquid at 250° F., and has a specific gravity of from 1.05 to 1.1.

Before the earthquake, the Western Fuel Co. paid \$10.50 per ton for the ordinary pitch "D" delivered at its plant, while a properly and carefully prepared pitch was worth from \$12 to \$13.

Owing to the enormous building-activity in San Francisco since the earthquake, the demand for asphaltum for roofing-materials has increased in leaps and bounds. Consequently, there is a great scarcity, and the price per ton now ranges from \$14 to \$20. This scarcity necessitated many shut-downs of the plant at Oakland, and for that reason the company is negotiating for the importation of coal-tar pitch from the East and from Europe. As three new refineries are contemplated, conditions may gradually return to their normal stage.

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<sup>7</sup> *The Engineering and Mining Journal*, vol. lxxviii., p. 262 (1904).

<sup>8</sup> *The Engineering and Mining Journal*, vol. lxxx., p. 389 (1905).

All of the coal purchased and used by the Western Fuel Co. is brought in ships and is unloaded by electric hoists into receiving-bins. When drawn from the storage-bins it is screened, all material passing through the perforations dropping into auxiliary bins, from which it is fed into a Williams crusher. The disintegrated coal from the Williams crusher is elevated into the iron hopper of an automatic feeder which feeds into the coal-heater. The heated coal enters the mixer and meets there the binder. The mixer as well as the binder-distribution and the tempering of the mixture embody some novel features.

The prepared material is conveyed into the feed-hopper of a Schorr press, style "A," which is belted for 6 rev. per min. At that speed 480 briquettes of 9.5 oz. weight are discharged in one min., or more than 17,000 lb. per hr. The briquettes are of a rectangular shape, 2.75 by 2.5 by  $1\frac{1}{8}$  in. thick, with rounded corners and branded with a "W." They are uniform in size, and have a specific gravity of about 1.22.

All wearing-parts of the press are lined with phosphor-bronze, and they are thoroughly lubricated under an air-pressure of 40 lb. per sq. in. Oil is also atomized and sprayed into the molds and upon the plungers.

The briquettes drop upon a short conveyor delivering the same to another one located outside the building. At this point provision is made to sack the briquettes for the local market, or to take them up to the top of the storage-bunkers, where arrangements are made to discharge the briquettes into cars or to distribute them into the bunker-compartments. The average output is 64 long tons per shift of 8 hr., four men being employed, one of them getting \$4, one \$2, one \$3, and one \$2.75 per day, which makes about \$0.20 per ton of briquettes. By running 24 hr. more than 200 tons could be made, which would reduce the labor item to about 14.5 cents per ton. This can be further cut down by speeding up the press to 7 rev. per min., which would produce 560 per min., or 20,000 lb. of 9.5-oz. briquettes per hr. With a forced-feed attachment a further increase in speed may be possible.

Since the foregoing was written, wages have been increased considerably, most of the men getting \$3.50 per shift, working through the lunch-hour.

The present pressure-arrangement was tested up to 48,000 lb., exerted upon two 2.5- by 2.75-in. surfaces, making more than 3,700 (?) lb. per sq. in. The adjustment is placed to give about 2,900 lb., which is ample, and makes a better-burning briquette than when a greater pressure is used. The press is designed for a maximum pressure of 6,000 pounds.

The briquetting-press has been described by Mr. Schorr substantially as follows:<sup>9</sup>

"In this press two sole-plates with heavy bearings are arranged to carry a stationary steel shaft, upon which a large spur-wheel is revolving, driven by means of gearing, countershaft and friction-clutch pulley. The spur-wheel rim is made integral with a mold-ring which has a series of holes and sliding plungers (pistons) therein. The pistons are under continuous control of cams which are supported by heavy shields. The pistons are released from the camway only when the final pressure is applied, and this is done by a large wheel with steel tire, pivoted in two levers.

"This wheel is pressed against the piston-heads by means of an adjustable spring, which permits a perfect regulation of pressure up to 4,000 lb. per sq. in. After leaving the pressure-wheel, i.e., after the briquette is made, the plungers are gradually forced forward to eject the briquettes, which drop upon a vibrating discharge-chute.

"The pistons are then gradually withdrawn, and in passing the feed-box the cavities become filled with the mixture of coal and pitch. At the end of this feed-box all surplus material is scraped off by a steel plate. After passing the scraper-plate the pistons are gradually forced in, pressing the material against the resistance-block, which is supported by the main shaft. This pressure is effected by a cast-iron stand with phosphor-bronze liner.

"When the pistons are about 0.5 in. from their terminal, they strike against the rocking pressing-wheel and are forced home. In this way the briquettes are made, and the play repeats itself with every revolution.

"The machine is entirely self-contained, and it is claimed that there is no possibility of its getting wrecked by overfeed or obstruction. It is also claimed that as the pressure is applied slowly and gradually, this type of press permits briquetting mixtures containing from 13 to 14 per cent. of moisture, and that this is an advantage not possessed by intermittently-acting presses. Up to the present time two press designs have been made, the one with two rows of 2-in. cylindrical molds, and the other with two rows of 2.5- by 2.75-in. rectangular shapes with rounded corners. There is no difficulty in making other shapes and heavier briquettes. A simple arrangement permits working with half the capacity whenever desired. No complications are presented if it is desired to have more than two rows of molds, and the type of press can be built for a much larger capacity. On the other hand, should the market for briquettes be limited for some months in the year, the capacity can be cut down without requiring any change in speed or other alterations.

"From 80 to 120 briquettes are made for each revolution, the number depending on the size and shape of the briquettes, which govern also the capacity. The

<sup>9</sup> *Engineering and Mining Journal*, vol. lxxx., p. 627 (1905).

same varies from 6 to 24.5 tons per hr. The briquettes are uniform in size and plainly branded with 'W.' "

Mr. Schorr says that all wearing-parts of the machine can be quickly and cheaply replaced. The lubricating is done by an air-compressor and oil-atomizer.

The press is especially adapted for the manufacture of small briquettes, and the use of such in preference to large blocks is obvious. Small briquettes can be readily shoveled into furnaces, while the large ones have first to be broken up, thus causing labor, waste, and dust.

A briquetting-plant of an entirely different type, designed by Mr. Chas. R. Allen, was built and put in operation by him during 1905 at Pittsburg, at the junction of the San Joaquin and the Sacramento rivers, about 50 miles from San Francisco. This plant, as originally projected, was intended to utilize the lignite produced by the Pittsburg Coal Mining Co. at Somersville, but the enormous increase in the production of oil in California has had such a demoralizing effect upon the coal-trade generally that there has been little or no market for lignite during the last two years, and these mines have been shut down. The material used has, therefore, been screenings obtained from the coal-yards of San Francisco, the binder (here, as at other plants in the State) being asphaltic pitch. The screenings are sold at less than the cost of mining lignite, and as long as the supply of this material is available at such prices it will continue to be used.

The methods of preparing the briquetting-mixture differ somewhat from those used at other plants in that the binder is passed, together with the fuel, through the retorts under a high degree of heat. This, it is claimed, insures an intimate and thorough mixture, each particle of fuel being impregnated with the binder. This treatment, it is asserted, prevents the binder from being consumed before the coal is ignited, which is apt to be the case, particularly with lignites, if the mixing is merely superficial.

Mr. Allen claims that in his process the nature of the fuel is changed so that the lignite partakes of the character of bituminous coal, the briquettes remaining firm and hard until entirely consumed. He claims also that the process possesses as much of novelty and value as the press.



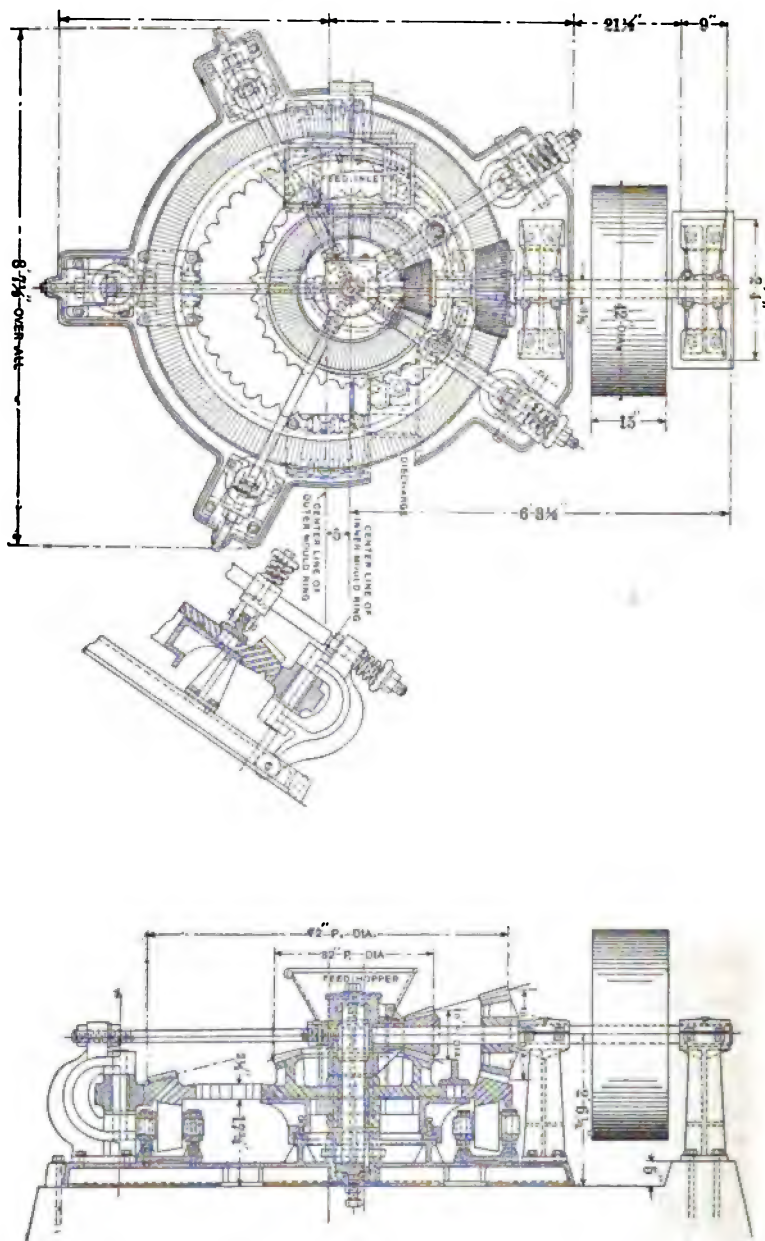


FIG. 11.—ALLEN BRIQUETTING-MACHINE. (Plan and Elevation.)

As shown in Figs. 11 and 12, the compressing-machine consists of two non-concentric rings horizontally placed, one within the other, the periphery of the smaller one being cor-

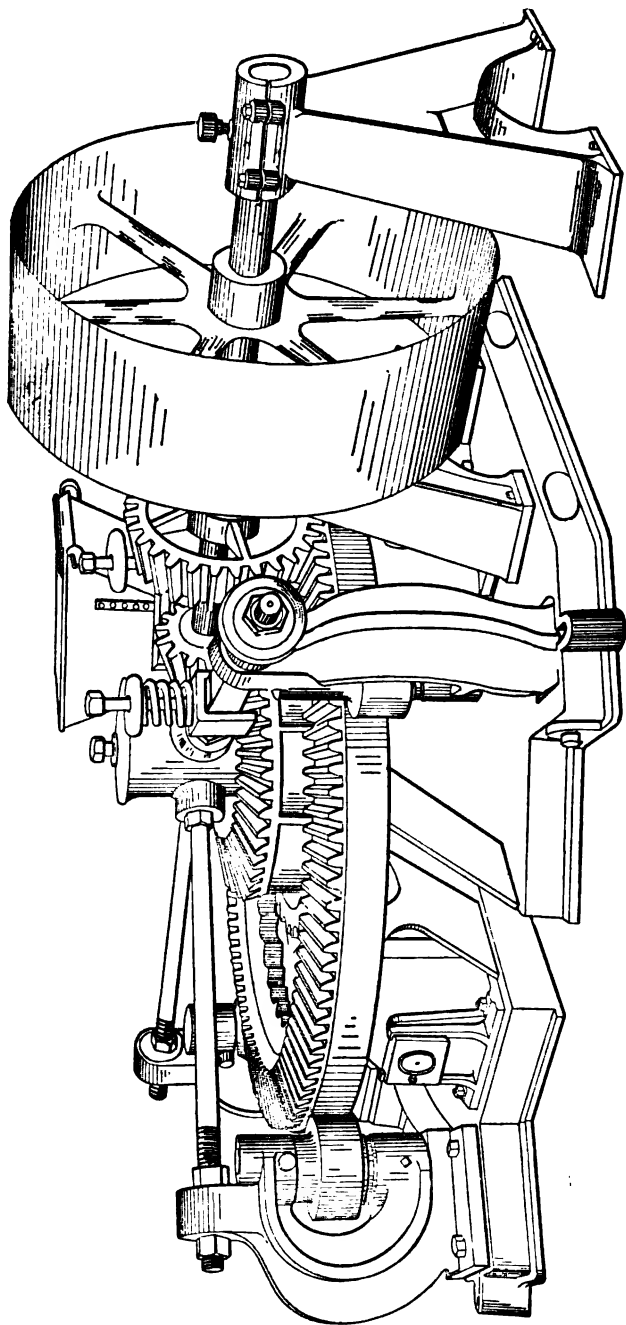


FIG. 12 —ALLEN BRIQUETTING-PRESS. (Perspective View.)

rugated, or scalloped, and engaging with similar corrugations in the inside of the larger ring. The briquetting-mixture is fed into a hopper one-fourth of a revolution of the smaller ring from the point of compression, and the amount of pressure is regulated by the distance of the feed from the point of compression; that is to say, the hopper may be placed further away if a greater pressure is desired, or nearer, if the pressure is to be reduced. Relief from an excess of pressure is provided for by two heavy spiral springs on the outer bearings, and two over the upper pressure-plate, the lower pressure-plate being fixed. The relief-springs are shown in Fig. 11. The machine has been operated without using any of the springs, with the result that when there was a surplus of feed the operating-belt was thrown off through the choking of the machine.

The Allen machine is patented.<sup>10</sup> The briquettes, as now made, are approximately cylindrical in shape, with flat ends. They weigh from 8 to 10 oz. each, and have a specific gravity of 1.14. It is Mr. Allen's intention to reduce the size of the briquette and change its shape by having the smaller ring of the press made without corrugations. This will be done in order to meet the demand for a briquette better adapted for domestic use.

The plant is at present turning out about 5 tons of briquettes per hr., at a moderate running-speed. With a smaller briquette the production per hour would be decreased, with the same speed, while with an increased speed the same production could be maintained, even with the smaller briquette.

The Standard Coal Briquetting Co., of Oakland, constructed in 1905 a plant designed by a Mr. Crawford. An accident to the press shortly after being put in operation practically wrecked it, and the enterprise was unsuccessful.

Another plant beginning operations in 1905 was a small plunger type of press designed by Mr. A. Demetrak, and built by the American Briquetting Co. (afterwards reorganized as the Ajax Briquetting Co.), of San Francisco. It was destroyed by the earthquake and fire of April, 1906, and has not been rebuilt. The plant had a capacity of about 15 tons a day, using Coos Bay, Ore., lignite, sometimes mixed with coal-yard screenings, and asphaltic pitch.

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<sup>10</sup> U. S. Patent No. 851,007, April 23, 1907.

The United States Briquette Co., of Stege, Contra Costa county, has undertaken the manufacture of briquettes from a mixture of peat and California crude petroleum. This plant had not been completed at the time of writing this report, but some briquettes made of the mixture in an experimental way are interesting productions. They give promise of a method of using California oil as a domestic fuel, the peat, on account of its spongy character, acting as a carrying-vehicle for the oil, and at the same time performing duty as fuel. The briquettes are cubical in shape and of attractive appearance. They weigh about 10 oz. each and have a specific gravity of 1.3.

It is claimed that they are as well adapted for steam-raising as for domestic purposes, giving an intense heat under forced draft, and burning freely under ordinary draft; that they can be handled without waste from breakage, and that they leave a minimum of ash and do not clinker.

#### ARIZONA.

The Arizona Copper Co., Ltd., of Clifton, installed, during 1905, a briquetting-plant purchased from Messrs. Yeadon, Son & Co., of Leeds, England. The plant was put in operation in September, 1905, and, during the first six months of 1906, produced 690 short tons of briquettes of a total value of \$4,830, or an average of \$7 per ton. About 300 tons were produced in the experimental runs made in 1905. It was installed for the three-fold purpose of utilizing coke-breeze, which is without value and non-usable as such; for securing better efficiency out of the slack coal (Gallup) which is used as fuel; and for obtaining a fuel that could be stored without material deterioration, and without danger of spontaneous ignition. Mr. James Colquhoun, president of the company, affirms that what economic advantages are secured are from the first and third operations. In the briquetting of the coke-fines or breeze a profit of about \$4 per ton is made in the conversion of a formerly-wasted material into a usable fuel. In using the Gallup, N. M., slack, which is of sub-bituminous, or black lignite, quality of coal, the expense of briquetting brings the total cost up to approximately \$6.80 per ton, or about the same as that of the lump coal obtained from the same source, although the price for the slack at the mines is very low when

compared with that of lump coal. The briquettes have been found to burn freely and satisfactorily under locomotive and stationary boilers, and appear to be equal to the best of Gallup lump coal, but no laboratory-tests of calorific power have been made.

The real profit in the briquetting of this coal is in the superiority of the briquettes over lump coal for stocking-purposes. They stand weathering perfectly, while the lump coal disintegrates upon exposure, loses a portion of its combustible gases, and becomes in time a very inferior fuel. It is also liable to spontaneous combustion, which the briquettes are not.

In the making of the briquettes 92 per cent. of the coal is mixed with 8 per cent. of California asphaltic pitch. The capacity of the plant is 2.5 tons of briquettes per hour.

The following description of the process at Clifton has been furnished by the company. In design the press is similar to the one used by the U. S. Geological Survey coal-testing plant at St. Louis. This was designated as the "English" machine, and has been described in the reports of those tests.<sup>11</sup>

The process of making briquettes of coal- or coke-fines is that of Yeadon, Son & Co., of Leeds, England. The fines are fed from the bins into the boot of a bucket-elevator, which discharges them into the hopper at one end of a mixer, where they are mixed with pitch that has previously been broken in a pitch-breaker into pieces of 0.5 in. maximum size. The quantity of pitch found to give the best results is about 8 per cent.

From the mixer the material is sent into a disintegrator, which thoroughly pulverizes the coal and pitch into grains of 2-mm. size and under. It is then elevated and passed into a heater, where it is subjected to the action of live steam, which gives the pitch sufficient fluidity to bind the other ingredients.

From the heater the material drops into a pug-mill which, while stirring the mass, sweeps it into a false bottom. This false bottom is behind the disk of the briquetting-machine, and, at each revolution of the main shaft, the material is rammed into a pair of compartments in the disk. The disk contains eight pairs of such compartments, and at the same time that a pair of briquettes is being rammed into the disk on one side,

<sup>11</sup> *United States Geological Survey Bulletin No. 261, and Professional Paper No. 48.*

another pair is being compressed on the opposite side, while a third pair is being pushed out from the top of the disk into an endless-belt conveyor, which delivers the briquettes to the side of a railroad-car in front of the building. The briquette-disk is made to revolve intermittently in eight periods to each complete revolution. During the pause in each period, the three operations referred to take place simultaneously.

The capacity of the plant is 25 tons per 10 hr. It is arranged to mix three ingredients into material for briquettes, but at present only the fines from coal or coke and pitch are used. The briquettes are rectangular in shape and weigh approximately 4 lb. each.

#### MICHIGAN.

The Semet-Solvay Co., of Syracuse, N. Y., has recently completed the construction of a briquetting-plant at Del Ray, to be operated in connection with the by-product coking-ovens and chemical-works installed there several years ago by the same company. The installation of the briquetting-plant was begun about two and a half years ago. As originally constructed, the briquetting-machine was a reciprocating-press of English make, but after carefully working out the process the company came to the conclusion that a press of the reciprocating type is adapted only to large briquettes, whereas the markets for which this product was intended demanded a small briquette for the domestic trade.

As the result of the experience gained with the English machine, the company has developed a process for the manufacture of small briquettes, and although this plant is just beginning to run it gives excellent promise.

The process consists essentially of the intimate mixing of finely-powdered pitch of proper quality and consistency with pulverized coal, so that theoretically each particle of coal is coated with the fine pitch. The mixture is then brought up to the proper temperature with steam, or steam and hot water, and is fed to a rotary Mashek press built by the Traylor Engineering Co., of New York. The output of the plant is from 10 to 15 tons of briquettes per hr. These are from 2.5 to 3 oz. in weight, and about 1½ in. square, shaped somewhat like a miniature sofa-pillow. This shape is satisfactory for shoveling and for handling in household stoves and furnaces. The company is using

a portion of coke-breeze with the coal and pitch, with a view to making use of the breeze from its coke-plant, and it is also experimenting on the best mixtures and the best grades of coal. The briquettes made so far are said to burn well and to give no smoke, except a slight puff when they are first thrown on the fire. As the plant is not yet in full running, some minor adjustments are still being made to perfect the product, but the operators are much encouraged by results so far obtained, and expect within a short time to be making a thoroughly satisfactory and commercial product.

#### MISSOURI.

*Renfrow Briquette Machine Co.*—During the summer of 1903, Governor W. C. Renfrow, of Oklahoma, became financially interested in a briquetting company in St. Louis. In the fall of the same year Mr. E. D. Mizner, of Hamilton, Ont., visited St. Louis to make a report for some Canadian interests relative to the purchase of the Canadian rights for the patents of this company. The results of these investigations, and the efforts of Governor Renfrow to force the briquette company to deliver a machine, ended in the bankruptcy of the company. In October, 1903, an agreement between Governor Renfrow and Mr. Mizner was made by which Mr. Mizner was to build a briquette-machine which would overcome the difficulties encountered with the former press. No company was organized at that time, but contracts were drawn satisfactory to the people interested.

The following spring, Mr. Mizner built the first Renfrow press, which made briquettes 2 in. in diameter, weighing about 4 oz. This press had some of the essential features of the present Renfrow press but made briquettes only at one end of the stroke; that is, 12 briquettes per revolution. After this machine was built it was discovered that the briquettes were too small and that the construction of the machine was too light. Mr. Mizner also developed the idea of making briquettes at both ends of the stroke, thus doubling the capacity of the machine. It was decided to build a much heavier machine, and one making a briquette 3 in. in diameter. Changes were also made in the method of mixing and heating the material. The cast-iron vertical heaters of the original press were supplanted

with horizontal jacketed heaters, using ordinary spiral-conveyor flights for mixing and handling the fuel. To this was added a short vertical heater acting as a reservoir, into which live steam was admitted just before the mixture was delivered to the molds.

The briquetting portion of the Geological Survey coal-testing plant at St. Louis during the Exposition has already been described.<sup>12</sup> After the close of the Exposition the "American" machine, installed by the National Compressed Fuel Co., of Chicago, was removed, and early in 1906 the remaining portion of the briquetting-plant was destroyed by fire. In rebuilding the plant provision was made for the installation of a Renfrow briquette-machine.

This machine was completed in the fall of 1905. Mr. C. T. Malcolmson, of the U. S. Geological Survey testing-plant, inspected this press at the shops of the Ramming Machine Co., at St. Louis, and burned some of the briquettes under a boiler at that plant. Difficulties were developed from the fact that the fuel remained too long in the vertical heaters, and some trouble was also experienced in getting the material from the die-filler to the die proper. Occasionally briquettes would stick in the dies, resulting in a double charge, which finally crippled the machine. Provisions were then made to overcome these difficulties and the machine was rebuilt. The new machine was first tested in March, 1906. The heating-capacity was increased so that the charge remained in the conveyors about 15 min. before reaching the dies, thus allowing the material to become thoroughly heated and the melted pitch to mix with the coal. Brushes were added to insure the charge being carried to its proper position in front of the die, and an ejector, operated by a magnet, insured the delivery of the briquettes from the ends of the plungers. Many of the parts of the machine were strengthened, and steel and bronze substituted for cast-iron in the wearing-parts. The results of the tests on this machine made under the supervision of Mr. Malcolmson for Mr. J. A. Holmes, Expert in Charge of the St. Louis fuel-testing plant, at the testing-plant of the company, resulted in a contract for the rental of this machine by the

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<sup>12</sup> *U. S. Geological Survey Bulletins* Nos. 261 and 290, and *Professional Paper* No. 48.



Government. In May, 1906, the first successfully-operating Renfrow machine was installed at the fuel-testing plant. It is shown in Fig. 13.



FIG. 13.—RENFROW BRIQUETTING-PRESS AT THE GEOLOGICAL SURVEY TESTING-PLANT.

The result of the tests which have been made on the Renfrow machine from May, 1906, to March, 1907, indicated that the design of this press was, in the main, satisfactory, and that

the difficulties experienced were due almost entirely to bad or weak construction of the machine. This machine was the result of many changes, while in many cases it was impossible to strengthen the weak parts owing to the limited space, or the fact that the size of the part was fixed by the original design.

The difficulties encountered in operating this machine at the coal-testing plant soon indicated its weaknesses, and as a result the Renfrow Co. designed and built two new presses, one of which was installed and is now being operated by the Western Coalette Fuel Co. at Kansas City. The other is now ready for delivery to the fuel-testing plant at the Jamestown Exposition. The new press makes a briquette 3.25 in. in diameter, weighing about a pound. The machine which was operated at the St. Louis fuel-testing plant could not be depended upon to deliver more than 1,000-lb. pressure per sq. in. on the briquettes without seriously straining the frame of the press. The new machine will deliver a maximum pressure of about 2,500 lb. per sq. in. without straining the machine. All of the wearing-parts not under pressure are made of bronze so as never to become corroded, while the dies, made of case-hardened steel, are kept clean and bright by the abrasive action of the fuel. The cams and rollers, originally made of chilled cast-iron, are made of case-hardened tool-steel in the new machine, and the design of the housing has been so changed that any of the parts can be removed without dismantling the machine. Provision has also been made in the new machine so to feed the heaters that they will always run clean and at the same time keep a full load in the chamber above the die-filler. This chamber, while closed in the old machine, is open in the new, which allows the operator to regulate the supply of fuel to the press at all times. The plungers are arranged to make it practically impossible for a double charge to enter the press, and the length of the spring behind these plungers has been increased so that a double charge would not affect the press in any way.

Early in 1906 the Renfrow Briquette Machine Co. was incorporated under the laws of the State of Missouri with \$1,000,000 capital; W. C. Renfrow, President; J. M. Smith, Secretary and Treasurer, and E. D. Mizner, Superintendent. This concern is a close corporation, and the company will not

offer for sale any machines until after the Kansas City plant has proved successful. As far as can be learned, the construction of the Kansas City plant was brought about by the willingness of its President, Mr. J. H. Durkee, to accept a Renfrow machine without a guarantee, simply on the strength of the work done at the coal-testing plant. There are, of course, still some difficulties to be overcome, as is the case in the operation of any new plant, but in the main the mechanical operations of this plant are satisfactory, and the Renfrow Co. has been able to deliver what it contracted to do. Financial difficulties have threatened the life of the plant under the present organization, but Governor Renfrow has affirmed that he will not allow this plant to fail for this reason. A contract has been signed to deliver one of the machines to a company at Detroit, but under the terms of the contract no date is fixed for the delivery of this machine, and no guarantee from the Renfrow Co. has been required. Governor Renfrow is also authority for the statement that the Detroit machine will not be delivered until after the Kansas City plant has been successfully operated and put on a commercial basis.

The Renfrow Briquette Machine Co. has no plant of its own, but has under consideration the establishment of a factory in St. Louis. All of the machines above mentioned were built in machine-shops under contract. The Kansas City machine was built by the Excelsior Tool & Machine Co., at East St. Louis, and all of the other machines by the Ramming Machine Co., of St. Louis.

#### NORTH DAKOTA.

During 1905 ex-United States Senator W. D. Washburn, President of the Washburn Lignite Coal Co., erected a small plant at Minneapolis for experimental work in the briquetting of North Dakota lignite. The plant was too small to be operated successfully from a commercial standpoint. Several hundred tons of briquettes were made on this press without the use of a binder. The briquettes proved a satisfactory fuel for domestic purposes and for stationary boilers, but were not adapted to locomotive use, because the heavy exhaust-draft in the locomotive has the effect of disintegrating the briquette before combustion and causes the throwing-off of large sparks. This

small experimental plant represents the extent of Senator Washburn's efforts to briquette North Dakota lignites.

Mr. Robert L. Stewart, also of Minneapolis, who is interested in lignite-properties near Kenmare in Ward county, reports that he has been conducting a series of experiments with a view to the briquetting of this fuel, and as a result of his investigations the American Briquetting & Manufacturing Co. has been organized, which contemplates the construction, during the present year, of a briquetting-plant in North Dakota, convenient to the lignite-deposits, the plant to have a capacity of 1,000 tons of briquettes per day. Mr. Stewart says that the briquettes can be manufactured at a cost not to exceed \$2 per ton f.o.b., this cost including the expense of mining the lignite and delivering it to the briquetting-plant.

#### TEXAS.

Three companies have been organized in Texas recently for the purpose of briquetting the lignites which occur in great abundance through the eastern part of that State. These are the International Compress Coal Co., of Houston; the American Lignite Briquette Co., of San Antonio, and the Eureka Briquette Co., of Rockdale. The plant of the last-mentioned company has been erected and is ready for operation at the time of the writing of this report, except for the fact that the drying-apparatus has been found too small, and the plant has been shut down pending the erection of a larger drier. The details of the plant have not been obtained.

The American Lignite Briquette Co., while incorporated at San Antonio, will locate its plant at Rockdale, and the plant will be operated in connection with the lignite-mines of J. J. Olsen & Son. The company has purchased a press made by the Klein Briquette Co., of St. Louis, and the plant will probably be in operation by the time this report is ready for distribution.

The International Compress Coal Co. has been negotiating for the construction of a plant, but no actual building had been begun at the time of writing this report. All of these plants expect to use asphaltic pitch made from heavy Texas oil.

## FLORIDA.

In September, 1905, the Orlando Water & Light Co., of Orlando, completed the installation of a plant for the treatment and briquetting of peat, which occurs abundantly in the low-lying lands of Florida. The plant is located about 3 miles from Orlando, on the border of a peat-bog, from which its supply is drawn. As originally installed, this plant consisted of a macerating-machine or pug-mill, in which the fiber of the peat is entirely destroyed, and a brick-press. The briquettes, as they came from the press, were about the size of an ordinary building-brick, and when dried in the sun shrunk to about one-fourth their former bulk and lost from 75 to 85 per cent. in weight. The briquetting-feature of the plant was abandoned in the summer of 1906, as it was found that this part of the work represented 75 per cent. of the total cost, and that a satisfactory fuel could be made without briquetting. The method of treatment at the present consists simply of "machining" the peat in the pug-mill and dumping it in masses of several hundred tons. As the peat dries it shrinks and cracks into large irregularly rectangular blocks, which are broken off from the heap and stored. When thoroughly dried these blocks make a good hard fuel, which, it is stated, may be used for both locomotive and stationary boilers, for household purposes, and for the manufacture of gas. Tests of the machined peat for producer-gas at the U. S. Geological Survey coal-testing plant gave excellent results.<sup>18</sup>

The machine used at the Orlando plant was built by the Moore & Wyman Elevator & Machine Works, South Boston, Mass., under patents issued to the late T. H. Leavitt, of Boston.

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<sup>18</sup> Report on Peat, by M. R. Campbell, *U. S. Geological Survey, Mineral Resources of the United States*, 1905, pp. 1319 to 1322.

## **The Occurrence of Nickel in Virginia.**

BY THOMAS LEONARD WATSON, BLACKSBURG, VA.

(Toronto Meeting, July, 1907.)

### **INTRODUCTION.**

SULPHIDE ore-bodies of more or less lenticular shape occurring in metamorphic crystalline schists, gneisses, and slates, and conforming closely in strike and usually in dip to the enclosing rock, have been recognized and described along the Atlantic seaboard from Quebec to Alabama. The ore-bodies do not entirely conform, in all cases, to the structure of the enclosing schists, but they sometimes cut across the foliation in dip, though conforming more closely with the direction of strike.

In composition the principal sulphide mineral is usually pyrite or pyrrhotite, or both, accompanied by copper, frequently gold, and almost always some sphalerite and galenite. Other metallic ores are, so far as these sulphide bodies have been investigated, less common; silver is not uncommon, and in some of the pyrrhotite masses nickel is present in quantity sufficient to be commercially valuable. Cobalt frequently accompanies the nickel, usually in smaller amount, and the two vary much in relative proportion.

Quartz and calcite are probably the most common of the non-metallic minerals. A number of silicate minerals are frequent representatives in one place or another; garnet, amphibole, biotite, pyroxene, zoisite and others.

The sulphide bodies of Virginia, comprising both pyrite and pyrrhotite, are among the most extensive along the Atlantic seaboard. Among the pyrite bodies may be mentioned the well-known and extensively worked mines of Louisa and Prince William counties, located on the main pyrite belt (A, Fig. 1) of the middle and northern, eastern Piedmont region in Virginia, and among the pyrrhotite bodies is the famous "Great Gossan Lead" (B, Fig. 1) of the Floyd-Carroll-Grayson coun-

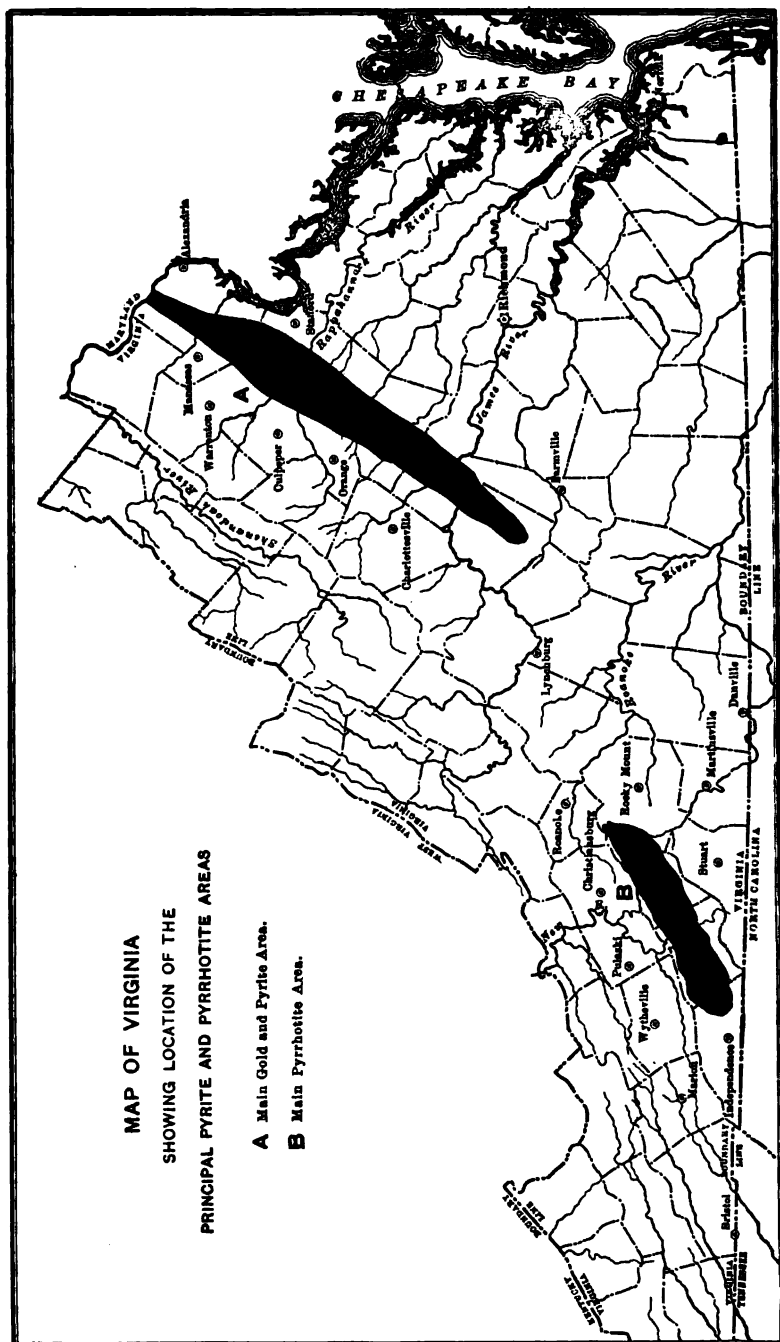


FIG. 1.—SKETCH-MAP OF VIRGINIA, SHOWING PYRITE AND PYRRHOTITE BELTS.

ties plateau in southwest Virginia. Both nickel and cobalt, in minute quantities, are reported in association with the pyrrhotite bodies of the plateau region of metamorphic crystalline rocks in southwest Virginia, but, so far as I am aware, the working of them for either of these metals has never been seriously contemplated.

It is the purpose of the present paper to treat in some detail of a recently exploited body of niccoliferous pyrrhotite in the extreme northwestern corner of the Floyd county portion of the Floyd-Carroll-Grayson plateau, shown in Fig. 2. This deposit does not belong to either of the classes outlined above, but is associated with basic igneous rocks, the principal types of which are not unlike those of Sudbury, in Ontario, Canada.

#### LOCALITIES OF NICCOLIFEROUS-ORE OCCURRENCES IN VIRGINIA.

The existence of nickel in Virginia has been reported from a number of localities in the Piedmont region or crystalline area, especially in association with many of the extensive pyrrhotite bodies of the Floyd-Carroll-Grayson plateau in southwest Virginia, and in Amherst county, near and to the east of Lynchburg. In Amherst county, the pyrrhotite is somewhat sparingly developed as small grains and moderate-sized granular masses, in crystalline schists, partly hornblendic, of doubtful origin. More recently, nickel in association with peridotite masses has been reported from near Broadrun station, in Fauquier county, northern Virginia; but this locality has not yet been investigated.

Reliable analyses of the southwest Virginia pyrrhotite bodies, giving the exact percentages of nickel and cobalt, are unfortunately not available.

#### DEVELOPMENTS AND VALUE OF THE ORE.

The property described in this paper is controlled by the Virginia Nickel Corporation, which, from 1904 until recently, exploited the area under the name of Fidelity Exploration Co. Fig. 2 indicates openings made at four different places. Some of these are in schists and contain pyrite instead of pyrrhotite as the ore. This paper will be confined to the occurrence and genesis of the nickel at the Lick Fork openings.

This occurrence of pyrrhotite has been known for many years.



The ore was dug and copperas made from it in a very crude way before the Civil War. The Lick Fork openings, Fig. 3, comprising shafts and drifts, were begun in the hard-rock out-

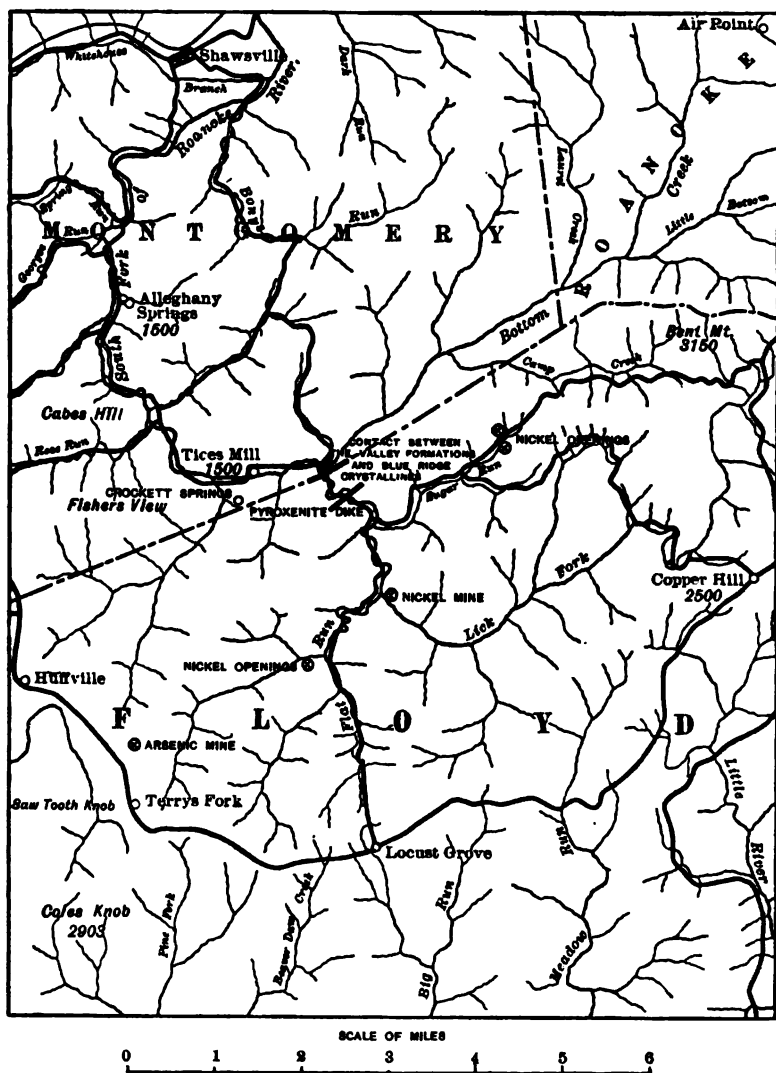


FIG. 2.—MAP, SHOWING LOCATION OF NICKEL- AND ARSENIC-MINES IN FLOYD COUNTY, VA.

crops at the base of a high and steep ridge, a few feet above the stream-level, and sunk less than 100 ft. below water-level. At the time of my visit, in May, 1907, a large amount of ore

on the dumps was reported to average by actual assays not less than 1.75 per cent. of nickel, and a fraction of 1 per cent. of copper. As much as 0.4 per cent. of cobalt was reported; but the average is considerably less. Assays of the pyrite from other openings in the area are reported to yield from 3 to 4 per cent. of nickel.

Arsenopyrite (mispickel) is mined less than 4 miles southwest of the Lick Fork openings, but numerous analyses made of the ore do not show the presence of either nickel or cobalt.

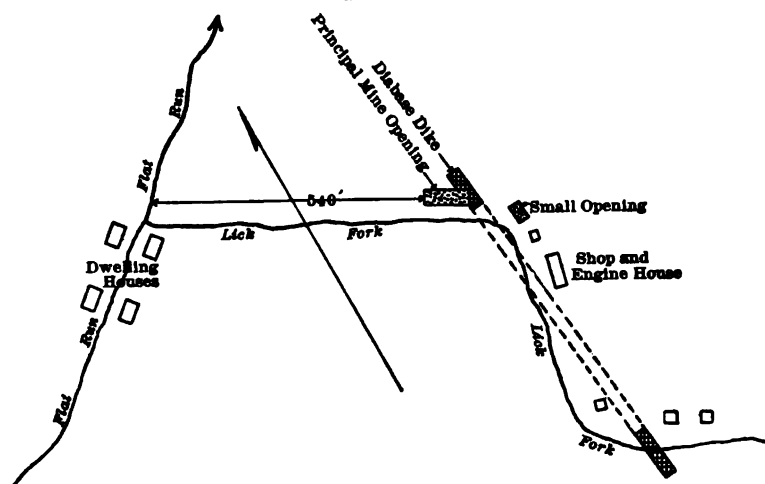


FIG. 3.—GROUND-PLAN SHOWING LOCATION OF OPENINGS AT NICKEL-MINE, NEAR HEMLOCK, FLOYD COUNTY, VA.

#### LOCATION AND TOPOGRAPHY OF THE AREA.

*Location.*—As indicated on the accompanying map, Fig. 2, the area here described lies in the extreme northwestern part of Floyd county along the boundaries of Montgomery and Roanoke counties. The openings thus far made are wholly in Floyd county, the principal ones being directly on Lick Fork, within a few hundred feet of its confluence with Flat Run, the SE. headwaters of the South Fork of the Roanoke river. The Lick Fork openings are further located in a direct line from Shawsville, the nearest railway station, 7 miles nearly SSE. The openings are aligned along a nearly NE.-SW. direction for a distance of about 4.5 miles.

*Topography.*—Fig. 2 shows the area to be a part of the strongly dissected portion of the extreme NW. part of the

Floyd-Carroll-Grayson counties plateau region. The main divide of the Blue Ridge is several miles further eastward, and the western margin of the Shenandoah limestone of the Valley region is less than 3 miles NW. in a direct line. Only one other mining-operation is located in the immediate area—namely, the mines and milling-plant of the U. S. Arsenic Mines Co., less than 4 miles SW. in a direct line from the principal nickel openings on Lick Fork. The mines of the arsenic company are practically on the divide between the north- and south-flowing waters of the plateau region, the nickel-bearing area being within the headwater-drainage of the north-flowing streams.

The area is one of strong surface-relief and of the mountainous type of topography, the higher ridges and knobs rising to elevations of from 2,500 to 3,000 ft. above mean tide-level. In the immediate vicinity of the principal openings on Lick Fork, the surrounding ridges rise about 600 ft. above the stream-level, the altitude of these openings, made at approximately local stream-level, being about 1,900 ft. The average elevation of the area is probably about 2,500 ft.

#### GEOLOGY AND PETROGRAPHY.

The area is composed exclusively of crystalline metamorphic rocks derived in part from original sediments and in part from igneous masses. It has been one of profound deformation, the results both of anamorphic and katamorphic changes being strikingly manifested in the rocks.

The rocks will be separately discussed under (a), the country-rock, and (b), the rocks immediately associated with the ore. The latter are igneous in origin, are much less altered from metamorphism, and are intruded into, and therefore later in age than, the country-rocks.

(a) *The Country-Rock.*—The country-rock is chiefly made up of a complex of micaceous quartz-schists and gneisses of variable composition, and usually of a pronounced thinly foliated type. Feldspar may or may not be a principal constituent of the schists; more often it is nearly or essentially absent. The gneisses, on the other hand, carry feldspar as one of the most abundant minerals. The country-rocks are undoubtedly derived, in part at least, from original sediments, while a part can be probably referred to altered igneous masses.

Talcoose and chloritic schists are found in places. East of the openings on Lick Fork, and within less than a mile along the stream, a medium-textured, highly quartzitic rock, composed largely of pale and deep blue opalescent quartz with some feldspar and a dark green pyroxene or amphibole, is exposed, and still further east fine-grained granite occurs. Toward the southwest end of the area and within a mile of the arsenic-mines the rock is a talcoose schist in places. At the arsenic-mines still other rock-types are distinguished, the principal ones being a silvery white, very thinly foliated quartz-sericite schist, with occasional bluish quartz "eyes," and a feldspar-quartz (bluish opalescent quartz)—biotite gneiss, the origin of which is in doubt.

At the contact of the Paleozoic sediments of the Valley region with the crystallines, less than 3 miles NW. of the Lick Fork openings, the principal rock on the crystalline side is an irregular syenitic gneiss of thin foliation and highly feldspathic. It is porphyritic in places, the pinkish feldspar phenocrysts being usually elongated in the direction of the gneissic structure. Exposures of the variable syenitic gneiss are found at many points over the western part of the area, probably indicating a considerable belt of this rock.

(b) *Rocks Immediately Associated with the Ore.*—These are without exception of igneous origin, and range in composition from a pyroxene syenite (akerite, according to Brögger) to a very basic gabbro. Two distinct types of the gabbro are sharply defined in the Lick Fork openings—namely, olivine-diabase, and the ore-bearing gabbro proper. These are separately discussed below.

The structural relations of the syenite, diabase, and gabbro, as indicated in the larger opening on Lick Fork, are shown in Fig. 4. The diabase and gabbro seem to be later in age than the syenite, which they apparently penetrate in dike-like form. Evidence is lacking as to the exact age-relations of the gabbro or ore-bearing rock and the diabase. The diabase is in direct contact, as a hanging-wall, with the gabbro; has an average thickness, so far as the openings extend in depth, of from 8 to 10 ft., and an outer contact with the syenite, as its own hanging-wall.

In May, 1907, the openings were nearly filled with water, which prevented access to them and doubtless left much that

might otherwise be cleared up from an underground study. I was reliably assured, however, that the contact between the gabbro and diabase was entirely sharp and without gradation of the two rocks into each other. It is entirely plain that since the last intrusion of igneous material the three rocks, syenite, gabbro, and diabase, have been subjected alike to intense dynamic strain, resulting in extensive fracturing, and otherwise altering them to some degree.

*Pyroxene-Syenite.*—Pyroxene-syenite, the rock into which the ore-bearing rock is immediately intruded, is, in its typical development, a coarse-grained dark grayish-green aggregate of feldspars and dark pyroxenes with, in places, a sprinkling of quartz and biotite, and usually garnets. It is strikingly similar,

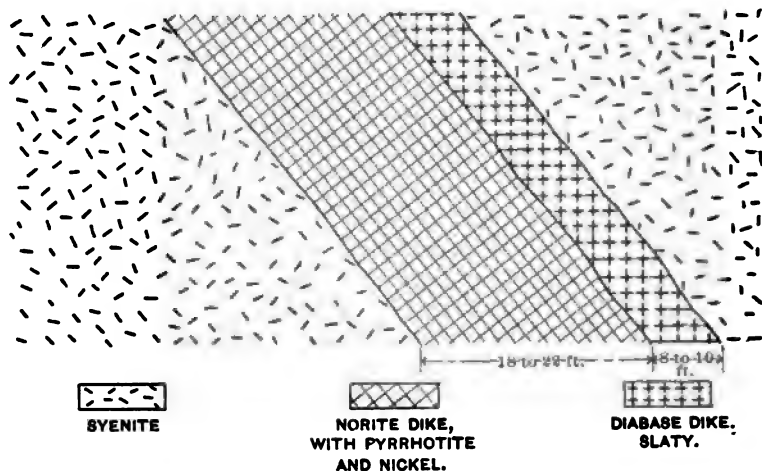


FIG. 4.—SECTION OF NICKEL-MINE, NEAR HEMLOCK, FLOYD COUNTY, VA. SHOWS STRUCTURAL RELATIONS OF THE SYENITE, DIABASE, AND GABBRO.

both in hand-specimens and in thin sections, to the unakite-bearing rock of Madison county, Virginia, in the northern Blue Ridge region, described by Phalen as hypersthene akerite, and later traced by me through several adjoining counties in the same region.

The syenite has not been identified on the higher ridge-tops of the area, but is found exposed at considerably lower elevations on Flat Run and Lick Fork. It has not been definitely identified at a greater distance from the Lick Fork openings than two miles. The outcrops at different places vary in color and texture from the normal coarse-grained, dark, grayish-green rock, with only an occasional recognizable quartz-grain,

to one of lighter color and from similar coarse to finer texture, in which a fair sprinkling of quartz occurs and a considerable development of garnet. In the finer-textured rock, biotite is frequently present in large amount.

In thin section the following minerals were noted: Orthoclase, plagioclase, microcline, pyroxene, biotite, hornblende, quartz, garnet, and the usual minor accessory minerals and alteration-products common to syenitic rocks. Pyroxene is the only essential ferromagnesian silicate, though biotite appears in nearly every thin section except two, sparingly in some but nearly equaling pyroxene in others, and hornblende is by no means rare. Feldspar is much the most abundant mineral, and is occasionally intergrown with quartz in micrographic structure. Microcline is present in most of the sections, and in many it is hardly less abundant than orthoclase and plagioclase. Plagioclase equals and in some sections exceeds the potash feldspar in amount, and the rock might perhaps with equal propriety be called a monzonite. In the absence of a complete chemical analysis, however, the name syenite is retained for the rock.

Analysis of a similar syenite (hypersthene akerite) from Milams Gap in the Blue Ridge of northern Virginia, analyzed and described by Phalen,<sup>1</sup> will give a general idea of the composition of the Floyd county syenite.

*Hypersthene Akerite (syenite) from Milams Gap, Virginia.*

*W. C. Phalen, Analyst.*

	Per Cent.
SiO <sub>2</sub> , . . . . .	60.52 <i>a</i>
Al <sub>2</sub> O <sub>3</sub> , . . . . .	16.99
Fe <sub>2</sub> O <sub>3</sub> , . . . . .	0.60
FeO, . . . . .	6.53
MgO, . . . . .	1.59
CaO, . . . . .	4.58
Na <sub>2</sub> O, . . . . .	2.83
K <sub>2</sub> O, . . . . .	3.91
H <sub>2</sub> O, . . . . .	0.88
P <sub>2</sub> O <sub>5</sub> , . . . . .	0.74
MnO, . . . . .	0.25
ZrO <sub>2</sub> , . . . . .	trace
Cr <sub>2</sub> O <sub>3</sub> , . . . . .	trace
TiO <sub>2</sub> , . . . . .	n. d.
Total, . . . . .	99.42
<i>a</i> Includes TiO <sub>2</sub> .	

<sup>1</sup> *Smithsonian Miscellaneous Collections*, 1904, vol. 45, p. 311.

Extinctions measured against the twining lamellæ of the plagioclase indicate a feldspar of about acid labradorite composition. Evidences of strain are manifested both in the feldspar and in the quartz by frequent wavy extinction and fracturing, and in the former mineral by occasional bent lamellæ. The usual alterations of the feldspars and pyroxenes are noted, but are not important at this time.

Garnet is present to some extent in nearly every thin section, and in many it is considerable in quantity. Most of the hand-specimens of the rock show little or much of the mineral. It is entirely secondary, as its position in the sections indicates its derivation from the interaction of the feldspar and ferromagnesian minerals, usually pyroxene. It is present usually in large irregular granular masses and in every case it is greatly fractured. It is probably the common variety of calcium-iron garnet, andradite. The other minerals do not call for description here.

Fractures common to most of the minerals, a partly peripheral granulation of the light-colored minerals, occasional bent lamellæ of the plagioclase, and wavy extinction of the quartz and to some extent the feldspar, are microscopic evidences of strain in thin sections of the rock. Every outcrop of the rock shows extensive fracturing, the numerous irregular fractures crossing each other in nearly every direction, frequently breaking the rock into small irregular masses.

*Olivine-Diabase.*—So far as the opening extends in depth, the olivine-dabase occurs on the hanging-wall of the ore-bearing gabbro, in dike-like form, averaging in width from 8 to 10 ft. and separating the gabbro from the syenite. As indicated in Fig. 3, the dike is exposed in and crossed by Lick Fork after its first bend from the mine-openings, distant from the latter about 500 ft. These two neighboring exposures of presumably the same dike indicate a trend of N.20°E., and, as shown in Fig. 4, a dip of 45° to 60° ESE. Its micro-structure and composition are those of typical fine-grained olivine-dabase. Olivine is abundant in large micro-porphyrific grains and crystals. Apart from the plagioclase laths and the augite, a sparse sprinkling of iron sulphide occurs, apparently of primary origin.

Like the syenite, the diabase is extensively broken by fracture-lines, which cause it to break into small irregular, more or

less rhombic, blocks when struck with the hammer. In the unweathered rock the diabase appears entirely massive, but specimens quarried from near or just above the water-level and exposed to the air for some time show a parting closely similar to slaty cleavage. In these weathered specimens of the rock, pyrite is visible to the naked eye, and some of it is of secondary origin, formed along the parting-planes mentioned above.

*Mica-Gabbro (Ore-Bearing Rock).*—Fig. 4 shows the relations of the ore-bearing gabbro to the syenite and olivine-diabase. It has an average width in the present main opening on Lick Fork of from 18 to 22 ft., and like the diabase it dips from  $45^{\circ}$  to  $60^{\circ}$  ESE.

It is a uniformly dark, dense, medium- to fine-grained rock, in which the somewhat abundant biotite shreds are easily recognized by the unaided eye. Megascopically it appears to be entirely made up of the dark silicate minerals and the metallic sulphides. The nature, distribution, and occurrence of the sulphides are described below. In the hand-specimens the rock appears entirely massive and without evidence of alteration of any kind.

Examination of a reasonably large number of thin sections shows the rock to be composed of a greater preponderance of the dark silicate minerals than of the lighter-colored ones. Orthorhombic and monoclinic pyroxene, biotite, hornblende, olivine, and plagioclase, are the principal rock-minerals. Not all of these are found in any single section. Pyroxene, biotite, hornblende, and plagioclase are in largest amount. Hornblende is variable in amount, being large in some sections and small in others, and olivine was noted in only one or two sections, but in these it was in quite appreciable amount. Monoclinic pyroxene is the most abundant dark silicate, and in some sections orthorhombic pyroxenes were not identified. Biotite is present in every section, usually in considerable quantity, as a primary constituent. Accessory orthoclase is present. Quartz and garnet do not occur.

Usually the minerals show strong cleavage-development and are more or less considerably altered to the usual secondary products, with the separation of much black oxide of iron from the ferromagnesian minerals. Minute fractures are common



to all the minerals, and in many instances the biotite folia are bent and fractured across. Several sections showed chiefly areas of a fine mosaic of the minerals, especially the dark silicates, which undoubtedly represent mashing and granulation from pressure.

#### THE ORES.

The ore is chiefly pyrrhotite, with finely disseminated chalcopyrite inextricably intermingled. It is fine-grained and massive, and apart from manifesting a tendency to break along planes of weakness it shows no evidence of banding. The sulphides both replace and inclose the rock-minerals at times.

Separate nickel-minerals were not observed. Indeed, no investigation was made to determine whether the nickel was present as an essential constituent of the pyrrhotite, replacing in part the iron, or as a separate compound, as in the Sudbury district.

#### MODE OF OCCURRENCE OF THE ORES.

*Megascopic.*—The sulphides, pyrrhotite and chalcopyrite, chiefly the former, are quite freely distributed, but without striking regularity or uniformity, through the gabbro. In some parts of the rock the proportion of sulphides is very small; in others, they make up 50 per cent. and more of the total rock-mass, with all gradations between. The average ratio of sulphides to total rock-mass is considerably less than 15 per cent. It is not possible for me to say whether the ore-distribution favors any one zone, such as the foot- or hanging-wall, or the central portion of the rock, more than another. The exposures accessible to me in the openings were insufficient as data for a judgment on this question. A careful examination of the dumps, however, revealed some ore in nearly every piece of the ore-bearing rock, and I am reliably informed that the ore does not favor one zone in the rock more than another, but is distributed through the entire thickness of the ore-bearing rock—gabbro. The sulphides are distributed through the rock in small irregular areas, both connected and disconnected, and in stringers and veinlets, which penetrate the rock in all directions. These irregular small areas of ore may be composed entirely of sulphides, or the sulphides may inclose minute areas of the rock-minerals. Another occurrence is that of smaller isolated granular masses, resembling disseminations, such as



FIG. 5.—Photomicrograph of ore-rock, showing sulphides (dark) between folia of biotite (medium gray), filling fractures and entering cleavages. Light-colored areas, altered and unaltered pyroxene.  $\times 40$ .



FIG. 6.—Photomicrograph of ore-rock, showing sulphides (dark) rimming, penetrating and replacing pyroxene (white).  $\times 40$ .



FIG. 7.—Photomicrograph of ore-rock, with ore (dark) replacing the iron-bearing silicate-minerals, chiefly pyroxene, with some biotite (white) along cracks and cleavages. Small unreplaced residues of silicate-minerals (white) in large area of sulphides (dark).  $\times 40$ .



FIG. 8.—Photomicrograph of ore-rock, showing inclosures of biotite folia and pyroxene (white) in sulphides (medium gray). The dark area on right of figure is brownish-red chlorite derived from biotite.  $\times 40$ .

FIGS. 5, 6, 7, 8.—MICROSTRUCTURES OF NICKEL ORE-ROCKS, FLOYD COUNTY, VIRGINIA.

may ordinarily be observed in any basic igneous rock, and are usually regarded as original constituents of the rock.

*Microscopic.*—Microscopic sections indicate, as remarked above, that the rock has undergone some alteration, although every section shows that most of the original minerals are remarkably fresh, except frequently around the margins and along the fractures which penetrate into and sometimes cross the grains, and in some cases along the cleavage-directions. Many instances are noted in which the original mineral is almost completely altered, but the ratio of such to the entirely or nearly fresh mineral is exceedingly small.

Microscopic sections show the relations of the sulphides to the rock-minerals to be quite similar, in some respects, to the Sudbury and the Rossland examples described by Dickson.<sup>2</sup> The sulphides probably show closer association with the dark silicate-minerals pyroxene, biotite, and hornblende. The sulphides, filling fractures, are formed between the grains and along the cleavages, replacing the rock-minerals involved, either in whole or in part. These relations of the sulphides to the silicate-minerals, indicated in Figs. 5, 6, 7 and 8, show the marked tendency of the sulphides to follow lines of weakness, such as along fracture- and cleavage-planes and between grains. In each occurrence more or less of the silicate-mineral involved is usually replaced. Sulphide veinlets are frequently formed in the silicate minerals, especially the biotite, along the direction of cleavage (Fig. 5). Biotite is usually only slightly or not at all replaced by the sulphides, rarely entirely so, indicating, for those sections studied, at least, that it is one of the most-resistant minerals.

Frequently the sulphides show sharp outlines against the fresh silicate-minerals, but where the latter are cleaved and broken the sulphides tend to occur along these directions. The relations of the sulphides to the rock minerals, briefly stated above, are shown in Figs. 5, 6, 7 and 8. Attention is called to Fig. 7, which shows the massive ore inclosing small areas of unreplaced silicate minerals.

It is noteworthy that a very small proportion of the sulphides show relations to the silicate-minerals such as to suggest that

<sup>2</sup> Dickson, C. W., *The Ore-Deposits of Sudbury, Ontario, Trans., xxiv., 25-64* (1904).

they are primary and were among the first to crystallize. The proportion, however, is not greater than is ordinarily contained in a rock so basic as this one.

#### GENESIS OF THE ORES.

The description given above, both of the ore and the associated rocks, strongly suggests that the ore is chiefly of secondary origin. It occurs in an igneous rock, which in turn is intimately associated with others, and each shows visible evidence of deformation. The formation of most of the ore appears to have been later than the metamorphism of the rocks. In large part, the evidence for this is based on microscopic study, the results of which are briefly set forth above and need not be repeated here.

Concerning the source of the ore it is yet impossible to make a definite statement. Several possibilities present themselves, which, for lack of sufficient data, are not discussed, but, so far as there is evidence at hand, it is probable that the ore was the work of ascending solutions derived from great depth.

#### CONCLUSIONS.

In summary the essential facts developed in this paper are;

I. That the general area is one of crystalline metamorphic schists and gneisses, derived in part from original sediments and in part from igneous masses.

II. That the ore-bearing series of rocks, which is of igneous origin and intrusive into the schists and gneisses, comprises syenite, diabase, and gabbro. Gabbro is the ore-bearing rock and is in contact with syenite on the foot-wall and with diabase on the hanging-wall. Each of these types shows evidence of some metamorphism.

III. That the ore, averaging not less than 1.75 per cent. of nickel and comprising pyrrhotite chiefly, and a little intermingled chalcopyrite, is largely secondary and was formed after the metamorphism of the rocks. Microscopic sections show that from the relations of the sulphides to the rock-minerals the sulphides followed principally the lines of weakness in the silicate minerals, with considerable replacement of them.



### Blast-Furnace Practice.

Supplementary Note to the Paper of T. F. Witherbee on Blast-Furnace Practice, published in *Bi-Monthly Bulletin*, No. 15, May, 1907, pp. 523 to 536.

T. F. WITHERBEE, Durango, Mexico (communication to the Secretary\*):—In quoting Mr. Truran on the subject of moisture in the blast, I was obliged to rely upon my memory of what I had read 40 years ago, and I made some mistakes, to which Mr. Frank Firmstone has kindly called my attention.

I have just re-read Truran's *The Manufacture of Iron*, 2d edition (1867), and now write with more accuracy. On page 112 Mr. Truran says: "Taking the average of five years, selected promiscuously from twenty-two years' working, we find that at the foundry iron furnace the yield of coal per ton of pig-iron was, in the winter months, 49.7 cwts.; spring, 52.2 cwts.; summer, 53.1 cwts.; and autumn, 55.4 cwts. The excess of autumn over the winter months, 5.7 cwts., is equal to an increase of 11 per cent. At the forge iron furnace the yields in the winter months are 43.6 cwts.; spring, 44.2; summer, 44.6; and autumn, 45.8 cwts. The excess of autumn over winter, 2.2 cwts., is equal to 5 per cent. The variation of yield with the season is still more marked with the ballast iron furnace, the yields being, in winter, 43.2 cwts.; spring, 44.1; summer, 50.1; and autumn, 49.5, or 6.3 cwts. more in autumn than in winter, equal to 13 per cent. nearly." Recasting these data, the difference in fuel-consumption in favor of the dry period of the year is:

	Per Ton of Iron. Pounds.
Foundry iron furnace, . . . . .	638
Forge iron furnace, . . . . .	246
Ballast iron furnace, . . . . .	705

I can find no date or data that will give even a close approximation of the time that Mr. Truran wrote his work. It appears to have been written somewhere between 1827 and 1854, though he goes back to 1797 for some data. I can only say that it was

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\* Received July 26, 1907.

*not* “before Neilson’s invention of the hot blast,” as I stated in my paper, for “hot blast” was discussed perhaps more thoroughly than any other subject.

Truran discussed “hot blast” on the same lines that “dry blast” has been recently considered by some writers—viz., from the stand-point of heat-units alone—those carried in by the hot blast on the one hand and, on the other, those not needed to decompose the lesser quantity of water entering the furnace. In both cases the main point—the total effect—was missed.

**Proceedings of the Ninety-Third Meeting, Toronto,  
Canada, July, 1907.**

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The first session, held in the Banquet Hall of the King Edward Hotel, was called to order Tuesday, July 23, 1907, at 2.30 p.m., President John Hays Hammond presiding.

Prof. Willett G. Miller, chairman of the General Committee, introduced Alderman J. J. Graham, who, in behalf of the City of Toronto, extended a hearty welcome to the members and guests of the Institute. To this welcome, President Hammond replied in a few well-chosen and hearty remarks.

In the hall in which the session was held there was exhibited a fine, full-length, life-size portrait of Dr. Rossiter W. Raymond, in 1871 Vice-President and acting President, in 1872, 1873 and 1874 the elected President, in 1876 and 1877 Vice-President, in 1883, by appointment of the Council, and for the last 24 years by annual election, Secretary, of the Institute.

Dr. James Douglas, of New York, N. Y., on behalf of numer-



ous members, presented this portrait to Dr. Raymond, with a highly cordial and complimentary address.

Dr. Raymond, after acknowledging with gratitude and pride this testimonial of affection and approval, announced that he would immediately present the portrait to the Institute, in the rooms of which he hoped it might serve, after he had departed, to recall his face and bear witness of the friendly and flattering estimate which had been placed upon his work.

The Secretary announced that, upon the proposal of many members (including nearly all the past-Presidents of the Institute now living), the unanimous report of the Committee on Membership, the unanimous recommendation of the Council, Dr. Charles D. Walcott, late Director of the U. S. Geological Survey and now Secretary of the Smithsonian Institution, had been unanimously elected by the Board of Directors an Honorary Member of the American Institute of Mining Engineers, in recognition of his eminent professional contributions and official services to the science of geology, and of his cordial and efficient co-operation with the work of the Institute.

The following papers were presented in oral abstract by the authors:

The Destruction of the Salt-Works in the Colorado Desert by the Salton Sea, by William P. Blake, Tucson, Ariz.

Secrecy in the Arts, by Dr. James Douglas, New York, N. Y.

The second session was held at the same place on Wednesday, July 24, beginning at 10.30 a.m., President Hammond in the chair.

The Secretary, in the absence of the author, presented in oral abstract the following paper:

Corrosion of Iron Water-Jackets of a Copper Blast-Furnace, by George B. Lee, Douglas, Ariz.

The following papers were presented in oral abstract by the authors:

The Electric-Air Drill, by William L. Saunders, New York, N. Y. Mr. Saunders's paper, which was illustrated by lantern-views, brought forth an animated and interesting discussion by Messrs. D. B. Rushmore, Thos. J. Eynon, Wm. Kent, E. W. Parker, R. W. Raymond and W. L. Saunders.

Coal-Briquetting in the United States, by Edward W. Parker, Washington, D. C.

The Sands of the Athabasca District, by Dr. Robert Bell, Ottawa, Can. Dr. Bell's paper was discussed by Mr. Eugene Coste.

The third and concluding session, held at the same place, on Wednesday, July 24, was called to order, 2.30 p.m., by President Hammond.

The following papers, illustrated by lantern-views, were presented in oral abstract by the authors:

Notes on the Cobalt Mineral-Area, by Willett G. Miller, Toronto, Ont.

Notes on the Sudbury Mineral-Area, by Dr. Alfred E. Barlow, Ottawa, Ont.

The following papers were read by title for future publication by the Institute.

The Wilfley Table, by R. H. Richards, Boston, Mass.

The Occurrence of Nickel in Virginia, by Thomas L. Watson, Blacksburg, Va.

Geology of the Virginia Barite-Deposits, by Thomas L. Watson, Blacksburg, Va.

The Effect of High Litharge in the Crucible-Assay for Silver, by Richard W. Lodge, Boston, Mass.

Physical Factors in the Metallurgical Reduction of Zinc Oxide, by Woolsey McA. Johnson, New York, N. Y.

Zinc Oxide in Iron-Ores, and the Effect of Zinc in the Iron Blast-Furnace, by John J. Porter, Cincinnati, Ohio.

Chronology of Lead-Mining in the United States, by Walter R. Ingalls, New York, N. Y.

The Promontorio Mine, by Francis C. Lincoln, New York, N. Y.

Blow-Holes in Steel Ingots, by E. von Maltitz, South Chicago, Ill.

The Evergreen Copper-Deposit, by Etienne A. Ritter, Colorado Springs, Colo.

Pure Coal as a Basis for the Comparison of Bituminous Coals, by W. F. Wheeler, Urbana, Ill.

Quantitative Field-Test for Magnesia in Cement-Rock and Limestone, by Charles Catlett, Staunton, Va.

The Production of Converter-Matte from Copper-Concentrates by Pot-Roasting and Smelting, by George A. Packard, Boston, Mass.

Biographical Notices of 1906.

The Panoramic Camera Applied to Photo-Topographic Work, by Charles W. Wright, Washington, D. C.

Notes on the Present Source and Uses of Vanadium, by J. Kent Smith, Pittsburg, Pa.

The Mines of San Juan Nepomuceno del Doctor, by T. D. Murphy, Mexico City, Mex.

Discussion of Paper by H. M. Howe on Piping and Segregation in Steel Ingots, by Alfred C. Lane, Lansing, Mich.

#### MEMBERS AND GUESTS.

The following list is believed to comprise the names of members and guests who registered at the Institute Headquarters at Toronto, or attended, in whole or in part, the trip by train to Cobalt and return; nevertheless, so many came and went at various times during the meeting that this list is possibly incomplete.

#### *List of Members and Guests Registered at Toronto or Attending, in Whole or in Part, the Train-Trip to Cobalt and Return.*

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Miss E. Eilers, . . . . .	Brooklyn, N. Y.
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Mrs. L. Holbrook, . . . . .	New York, N. Y.
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Mrs. L. D. Huntoon, . . . . .	New Haven, Conn.
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Mrs. C. H. Lane, . . . . .	Cleveland, O.
Mrs. C. D. Lane, . . . . .	Cleveland, O.
Major Leckie, . . . . .	Cobalt, Can.
Capt. Jack Leckie, . . . . .	Cobalt, Can.
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Mr. G. E. Silvester, . . . . .	Copper Cliff, Can.
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Mrs. H. V. Winchell, . . . . .	St. Paul, Minn.
Mr. J. E. Wright, . . . . .	Sudbury, Can.

### THE TORONTO RECEPTION.

On Tuesday evening, July 23, a reception was held in the Legislative Chamber of the Parliament Buildings. His Lordship, Chief Justice Moss, Administrator of the Government, with Mrs. Moss and suite, received the guests, who numbered about 300.

Hon. Frank Cochrane, Provincial Minister of Mines, Lands and Forests, welcomed the visitors in a brief speech, referring to the benefit conferred upon Canada by such a gathering as that of the Institute, and then called in turn upon the speakers of the evening.

CHIEF JUSTICE MOSS: We in this Province are, perhaps, not yet able to boast that we fully rival the universities and technical schools in some of the neighboring States, as regards the teaching of the science of mining engineering; but I believe we are, at all events, alive to the interest, importance and necessity of such instruction. In the Faculty of Applied Science and Engineering in the University of Toronto, and also in the School of Mining in connection with Queen's University at Kingston, we are training men in this art and science, with encouraging results. To both students and teachers in that department, this visit of members of the American Institute of Mining Engineers must be an inspiration and a lesson, as it will likewise be to all who are interested in the progress and the solid prosperity of this country.

HON. J. J. FOY, Attorney-General: In welcoming our visitors, I regret the absence in England of the Premier of the Province, Hon. Mr. Whitney. I feel confident that even the



well-stored minds of our visitors will receive accretions of knowledge from their inspection of Ontario mines. The Government is proud of the mineral resources of the Province, and only anxious that experts should examine closely into those resources with a critical eye. We ask for no undue or undeserved laudation of our country; we only ask that you should see it carefully and well, and we do not doubt that the result will be advantageous to the country and the world. Our conviction that you will have a pleasant time is made perfectly sure by the fact that Hon. Frank Cochrane will accompany the visitors through New Ontario. You could not have a better cicerone.

JOHN HAYS HAMMOND, President of the Council of the Institute: Mr. Chairman, Your Honor, Canadian confrères, Ladies and Gentlemen: It is my very agreeable office to acknowledge, on behalf of the visiting members of the Institute, as well as for myself, our appreciation of your very cordial hospitality, and to express our recognition of the great work done in the development of the mining resources of America, and in the uplifting of the mining profession itself, by our Canadian confrères, of whom we hold in high esteem and friendship those whom it has been our good fortune to meet. His Honor, the Acting Lieutenant-Governor, in speaking of the Canadian technical schools and especially the mining schools, was, I think, altogether too modest in his estimate. I have had exceptional opportunities to "size up" the mining engineers of many parts of the world; and I can say in all sincerity that the result of my experience and observation has led me to regard the Canadian mining engineers, graduates of the Canadian mining schools, as the peers of those of any other country. In Canada, as everywhere else, the engineer is the real pioneer of civilization. Canada is greatly indebted to her engineers, not only for the development of a great mining industry, but for the schools and colleges that have contributed to the establishment of other very important industries; industries, indeed, upon which the prosperity of the country in a large measure depends. In mining, perhaps, more than in any other profession, there is, as Dr. Raymond said to-day, a spirit of fraternal enthusiasm. Certain it is that there is little of

that rivalry that tends to petty jealousies and estrangement between peoples of different nationalities. Emulation among engineers aims at the advancement of science; and in the domain of science there are no international boundaries, no racial antipathies. It is for this reason that I believe representative bodies of mining engineers are exceptionally well qualified to promote international amity; and while it is not my province to discuss international or any other politics, nevertheless I regard this as an opportune occasion to say a few words as to the reciprocal relations and duties of Canadians and Americans. Allied in blood, possessing a common heritage of literature and law, enjoying the same principles of self-government, striving for the same ideal of humanity and liberty in their national aspirations and policies, imbued with the same sense of right and wrong, these peoples of the Anglo-Saxon family are tied together by indissoluble bonds—bonds that no tension of commercial competition, no agitation of political demagogues, can in any wise sunder. At times, temporary differences, conflicting issues incident to the determination of disputed rights, will inevitably arise, and temporary misunderstandings will unfortunately be provoked; but these are mere transitory details in the broad scheme of the interfusion of our two peoples, whose solidarity of interest will always remain unimpaired and indisputable. It is no post-prandial platitude, but a most important postulate, that upon the co-operation of the members of the Anglo-Saxon family depends Anglo-Saxon supremacy. Therefore, it is our bounden duty, no less than our imperial interest, to discredit, if we cannot prevent, the agitation of the political demagogue or the sensational press on either side of the line. We Americans congratulate you of Canada upon the wonderful development of your illimitable resources. We see within your borders a vast industrial domain, and we desire to co-operate with you in your new field of activity, feeling assured that you will receive our services and our financial assistance in the same broad spirit of liberality that has characterized the policy of the United States in the development of its own resources.

Now a few words as to the mining industry. Through the investments of their citizens, Great Britain and the United States dominate the mining industry of the greater part of the

world, controlling as they do the chief fields of coal, iron, copper, lead, gold, silver and many other metals. If we engineers faithfully discharge our duties, safeguarding these investors, we shall not only increase the ascendancy of our countries in this regard, but also establish the mining industry and the mining profession upon a yet broader and more enduring basis. By conservatism, by honesty of purpose, by intelligence and technical skill, we shall make the mining field attractive to the capitalist, who even now is still somewhat inclined to regard mining rather in the light of a speculative venture than as the legitimate investment it should become. One result of the recent "boom" period has been the flotation of a great many worthless properties. To the credit of our reputable engineers be it said, that they were no parties to such nefarious transactions; nevertheless, the mining profession and the engineers have suffered in consequence. We should, therefore, sedulously endeavor to prevent the flotation of worthless mining properties by over-capitalized companies, and the undue "booming" of districts; for these things inevitably tend, not only to the irreparable injury of the districts concerned, but (what is a much more profound and far-reaching consequence) to the detriment of the mining industry and of the mining profession. In our efforts to discourage transactions of this kind, and to serve the permanent good of the mining industry generally, I ask the co-operation of the mining engineers of Canada, and I am sure that I ask not in vain.

DR. ROSSITER W. RAYMOND, Secretary of the Institute: This is the ninety-third meeting of our Institute, not counting special business meetings. At ninety of these I have been present, and have made this speech!

Do not infer that the Institute is ninety-three years old. In that case, though I should myself have the ripe age of one hundred and twenty-four, I might at least presume that I was addressing a wholly new audience. But no; these ninety-three meetings have been comprised in thirty-six years; and, though the memories of many dear comrades departed hover about me as I speak, yet I look into many a face, crowned now with white hair (or none at all!) which has kindly smiled upon me from the beginning. And you have no idea how thoroughly a

friendly audience can be drilled to hear old sentiments, and receive them with the affectation of fresh satisfaction!

There is a curious current error concerning the American Institute of Mining Engineers. People seem to think it is an ancient organism, like a majestic Saurian, which gets up periodically and travels to some new locality. On the contrary, the American Institute of Mining Engineers is everywhere, always. Our members are all over the world. We don't travel anywhere. We never had a place to start from, until Andrew Carnegie, one of our members, built us one. We have always been an omnipresent, pervasive atmosphere.

In the old days, before some of the men in our Institute revolutionized the art of making iron and steel, there used to be a good deal of iron made by puddling. The puddling-furnace is supposed to be (though it really is not yet) a back-number; but many of you remember what happens in puddling when pure iron begins to be formed, and all over the surface of the bath in the puddling-furnace appear little coagulations. A child would say the molten iron "cruddled." The workmen said it "came to nature." Now, a meeting of the American Institute of Mining Engineers is this all-pervading bath coagulating, or "coming to nature," in one particular spot. Our Canadian members who reside here and in this vicinity are simply the nucleus around which we "cruddle." And this thickening of our presence at one place is not by any means to be considered as a migration. When we go—I won't say home—but when we dissipate and go everywhere again, we shall not have left this place; we shall leave notable representatives here; we shall leave here new friends, destined, please God! to become old friends; and we shall still continue to be the circumambient environment of the material progress of this continent!

I must confess, after nearly a half-century of active professional life, that there are days when a man gets discouraged in the pursuit of truth. There is so much which we gray-heads learned in school that is not true any more;—volumes about the metallurgy of the past that have now nothing but a fanciful historic value! And we faint when we see the sums which the young men are doing, the graphic diagrams which they are drawing, the atoms, molecules, ions and electrons which disport around their fresh young heads; so that, once in a while, an old

fellow like me begins to feel as if knowledge was too much for him. Let him then come to a meeting of the American Institute of Mining Engineers, like this, and get the acting Premier or the Judge or the Attorney-General, or some distinguished and absolutely competent critic to tell him how much he knows, to tell him that he really is very distinguished, that they are so glad to have him come, because they think he will actually fructify the Province by the overflow of his great learning. Why, it sends a fellow home encouraged for another six months! I can assure you, Mr. Chairman, your flattery is not ill-bestowed, and I trust you will continue in that sweet hallucination after we are gone! We don't know as much as you think, but we wish we did!

This brings up again the very old, old trouble that I always have had in making this speech—a trouble peculiar to myself. Hammond knows how to do it; but then, he has not had to do it often! And the real thing that will commence to embarrass him by and by will be the consciousness that when he addresses the Institute of Mining Engineers he is talking to himself! There is something which used to be called, when I was a student in Germany of the Hegelian philosophy, the “subjective-objective.” Heine, in his burlesque *History of Philosophy*, has propounded a definition of it, which runs somewhat as follows: “The subjective-objective is as when a monkey boils his own tail, and is at one and the same moment objectively percipient of the process of boiling, and subjectively conscious of it!” That is the double consciousness which paralyzes the jaw of the most eloquent orator, because he cannot separate himself subjectively from the objective Institute in whose glory he so firmly believes. But Hegel's philosophy no longer dominates the world; and, at all events, the terrors of the “subjective-objective” have always been defied, as I defy them, here and now, by the strength of good, honest, frank, old-fashioned self-conceit.

We have been told over and over again—every new friend tells us in a new way—why we are so great; and why we are so successful; and why we are so numerous; and why we are so welcome; and everybody misses the one fact which it remains for me modestly to proclaim. The real reason is that we are the very finest folks that ever were—the most congenial

friends; the best travelers (ladies and gentlemen alike); the most ardently harmonious brethren. We go nowhere that we do not leave, like Watt's saints (but not like an automobile!), "a long perfume behind," of our good-will and our good deeds. Oh, we are very fine people! There is no use in mincing these matters; let us be frank for once! And that is the reason why, wherever we go, they tell us when we first come that they hope we will come again!

I have spoken a good many times on Canadian soil. Some of you remember that in Vancouver, two years ago, I paid a hearty tribute to the achievements of Canadian engineers; and some may recall my address on the same subject, made in 1889, at Ottawa, in the presence of that great man—great man, I say, whatever party judges him!—Sir John Macdonald. I could only repeat to-night what I have said before, but with added emphasis. Years ago, I supposed that the conquest of this continent had been completed. I remember being very eloquent, somewhere or other, about the way in which the American mining engineer went on into the wilderness; and how Nature, which had lain for thousands of years in sleep and solitude and silence, like the Beauty in the fairy tale, woke at his coming, and rose, and smiled and gave herself to him, with all the glory of her beauty, and all the bounty of her treasure. Oh, I was very eloquent about that! I thought it had all been done; and that we had done it—we Americans; and I told the young men of my generation that they might yet achieve great things, but not so great as the achievement of their fathers; that they might live to see wonderful epochs in human history, but there would be no future age like that, because there were no more worlds to conquer. The "winning of the West" I thought we had completed. But lo! here was another empire in the North; and that world, too, our tall Canadian brethren are conquering. All hail to them! May they do better than we have done! But let them never forget that we and they follow a common purpose and share a common glory!

DR. JAMES DOUGLAS, Past-President of the Institute: Dr. Douglas spoke of the cordial relations which he had found always existing between citizens of Canada and of the United States. He had left Canada thirty years ago, but always re-

turned to Canada a Canadian—not because he had not been well treated in the United States. He had been generously treated there, as every one who moved to the United States is treated. He told of having made an analysis in Canada, over thirty years ago, for which he was paid the magnificent sum of \$15; and the grudging way in which even that fee had been paid had been one of the considerations which induced him to emigrate to the United States, hoping to find there a higher appreciation of scientific work. Of course, things were very much improved now in Canada. Probably the largest undeveloped section of the mineral lands of the world, if we leave Siberia out of the account, is in Canada; and therefore, from a mining and metallurgical point of view, Canada has an immense future before it.

ROBERT W. HUNT, Past-President of the Council of the Institute, speaking from one of the desks allotted to members of the Provincial legislature, humorously assumed the position of a new and dazzling political dignity, but, soon adopting a more serious tone, recalled, in connection with the magnificent reception given to the Institute in Toronto, the similar occasions of former years, when even on the very verge of the Arctic Circle, its visiting members had received from resident members, and from government and citizens, a hearty welcome. He said that the people of Canada had a right to be proud of the revelation, during the last few years, in their magnificent Dominion, of riches previously unknown and undreamt. It had been his privilege, a year ago, as President of the Council of the Institute, to declare in the historic Guildhall of London that, of all the bright gems in the Imperial crown of Great Britain, none shone with so dazzling a luster as the Dominion of Canada. And this was especially true of the Province of Ontario, the agricultural and mineral resources of which were now astonishing the world. He thought the development of these resources by means of new railroads was one of the most remarkable episodes in human history, and called attention to the fact that, in the case of the most northern and most recent Canadian transcontinental line, the business already awaiting the railroad, or instantly created by its advent, was sufficient to pay its fixed charges—a phenomenon

which he regarded as unparalleled in the development of new regions by railroads. In conclusion, he said: "Canadians have a right to be both frankly proud and loyally patriotic. They do not need to be absorbed by anybody else. Canada is great enough, and strong enough, to be, as she is to-day, an Empire by herself!"

PROF. WILLIAM P. BLAKE, of Tucson, Ariz., one of the oldest members, and a past Vice-President of the Institute, was received with applause, and remarked that he must have been called upon because of his antiquity. His memory carried him back to the days of Sir William Logan, of Dr. Sterry Hunt and their associates, who worked upon the Canadian survey in 1852, when the great product of Canada seemed to be phosphate of lime. Later came asbestos and some other products, and the list had been largely increased. The mining engineers of the world are greatly indebted to Canada for the work done in geological exploration, and for additions to the literature of economic geology. He referred to Alfred C. Selwyn, who had succeeded Logan, and to Principal Dawson and his classic works upon geology. All these men and others, the list of whom might be greatly extended, had left a lasting impression upon geologic science, and had contributed largely to our knowledge of the structure and treasures of the earth. The work of economic geologists must rest upon the broad foundation of general geology; those foundations they laid for us, broad and deep, upon the rocks of Canada, the ancient rocks which cluster around Hudson's Bay. No mining engineer can travel and do his work without recognizing the achievements of the Canadian geologists.

After the foregoing addresses, refreshments were served in the Speaker's chambers. Music was furnished by the band of the 48th Highlanders, and social festivity continued to a late hour.

#### THE EXCURSION.

At 8 o'clock on the evening of Wednesday, July 24, a large party of members and friends of the Institute, including many ladies, left Toronto, as guests of the Provincial Government, for a week's excursion in northern Ontario, upon a spe-



cial train, consisting of ten Pullman and two dining cars, provided by the Government, and hauled free of charge by the railroad companies over whose lines it passed—namely, the Canadian Pacific, Grand Trunk, Canadian Northern, Temiskaming & Northern Ontario, and Manitoulin & North Shore. Similar courtesies were extended by the Temiskaming Navigation Co. and the O'Connor Steamboat Co.

Hon. Frank Cochrane, Minister of Mines, Lands and Forests, conducted the party, and was assisted by Hon. Dr. Pyne, Minister of Education.

#### *The Cobalt District.*

On arrival at Cobalt Thursday morning, the visitors were met by the following committee: A. A. Cole, representing T. & N. O. Ry.; R. W. Leonard and D. B. Rochester, from the Cobalt Chamber of Mines; Messrs. Running and Martin, from the Cobalt City Council; Messrs. McLeod and Ferland, from the Township Council of Coleman; and Messrs. Charles O'Connell, W. R. Askwith, J. W. Evans, R. A. Bryce, J. Edwards Leckie and W. H. Linney, Special Committee to look after the visitors.

This day and the day following were spent in visiting various mines at Cobalt, the party being divided into sections, and each section visiting four or five separate mines. Camp-dinners were served at the Coniagas, La Rose, Cobalt Lake, Nipissing and Cobalt Central mines.

The ladies of the party were charmingly entertained at the Cobalt Club by the Local Ladies' Reception Committee.

Very quaint and beautiful souvenir pins, made of leaves of native silver from the Trethewy mine, were distributed to the visitors.

The following sketch of the Cobalt district is condensed from the pamphlet programme of the Toronto Local Committee, prepared by Prof. W. G. Miller:

The veins of this area were discovered late in the summer of 1903. A year later, the Temiskaming & Northern Ontario railway was completed to Cobalt station, 330 miles north of Toronto. In 1905, the district produced 2,473,452 oz. of silver, valued at \$1,372,577; in 1906, the product was 5,357,830 oz., valued at \$3,543,089.

The veins occupy numerous small fissures (averaging probably 4 in. in width) and are very rich in silver, which occurs in native form, in true silver-ores, such as argentite, dyscrasite and pyrrgryrite, and in argentiferous ores of other

metals, such as niccolite, smaltite, cobaltite, tetrahedrite, etc. To give an idea of the richness of some of the veins, it is said that on one vein not more than 6 in. wide, an open cut 30 ft. deep and 50 ft. long yielded \$200,000. Single car-loads of 30 tons have yielded more than \$100,000. On the other hand, it has been estimated that in open cuts and surface-workings, the winning of the ore costs about \$100 per ton.

Most of the veins occur in the Lower Huronian conglomerate and graywacke slate. A few are found in the still older Keewatin, and a few in the younger diabase.

The peculiar paragenesis of the Cobalt vein-minerals is said not to occur elsewhere in America. Joachimsthal in Bohemia and Chalanches in France are cited as foreign examples.

The rocks in which these veins occur are geologically very ancient, the Keewatin igneous complex being so much older than the Laurentian that its rocks had been folded before the Laurentian rocks appeared. After that, there was a long period of erosion, deeply carving the surface; and lying upon this irregular surface are found the conglomerates, slates and quartzites of the Lower Huronian, in the fissures and interstices of which the Cobalt ores are chiefly found. After still further erosion, the Middle Huronian conglomerates and quartzites were deposited unconformably. Then there were intrusions of diabase and gabbro, the exact periods of which have not been determined; and finally, prolonged erosion laid bare at different places each of the formations named. It is believed that the eruptive diabase and gabbro both shattered and mineralized the rocks which they penetrated or overflowed. They show at present none of the characteristics (such as vesicular or amygdaloidal structure) of surface-flows, and are usually regarded as having formed laccolites or sills between the pre-existing strata. Since they penetrated the Middle, as well as the Lower, Huronian, there is, in Prof. Miller's opinion, no reason why the former should not be found, upon further exploration, to contain ore-deposits. The only suggestion to the contrary is furnished by the inquiry whether the conglomerates and quartzites of the second stage of the Huronian were as greatly fractured as their predecessors by the disturbances of the diabase eruptions. This question can only be settled by actual exploration.

#### *New Liskeard.*

On the arrival of the train at New Liskeard, at 8 p.m., Thursday, July 25, a deputation from the town was in waiting at the railway-station, headed by Hon. William J. Blair, the Mayor, who delivered an eloquent address of welcome. The deputation and their guests, in a festive procession of gaily decorated carriages, headed by a band, and accompanied by throngs of citizens on foot, then passed through the illuminated streets of the town, and under triumphal arches of welcome, to the steamer *Meteor*, upon which the evening was spent in a delightful moonlight excursion over the silver waves and along the shadowy shores of Lake Temiskaming. Refreshments were served on the trip; and speeches were made by Minister Cochrane, the Mayor, Secretary Raymond and Prof. L. D. Huntoon.

*Haileybury.*

The night was comfortably spent on board the special train, which returned Friday morning to Cobalt, for further visits among the mines, and at 4 p.m. proceeded to Haileybury, where the *Meteor* was again in waiting, to convey the party by daylight over the lovely lake which had been traversed by moonlight, the night before.

An intended visit to the (argentiferous galena) Wright mine, on the east shore, about 9 miles from Cobalt, was given up, on account of a strong unfavorable wind. This deposit is doubly interesting: first, because it is so unlike those of the neighboring Cobalt district; and, secondly, because it is one of the most ancient, if not the most ancient of Canadian mines. A map published in 1744, an engraving of which was given in the Local Programme of the Toronto meeting, shows that the locality, then called *Ance à la Mine*, was already known as a mine, and must have been known for some time before.

This lake-trip, like the one of Thursday night, went as far as "Devil's Rock," a precipitous headland, in the face of which mining operations have been carried on, as is shown by the mouths of adits high above the water. It is said that in the winter the miners made their camp on the thick ice below, and climbed up to their work, while in summer they were lowered to it by ropes from the plateau above. The strange absence of all waste dumps, such as generally appear at the mouths of mining adits, is explained by the circumstance that the miners have dumped all their waste into the lake, which is 200 ft. deep at the foot of the cliff.

Dinner was served on board the *Meteor* to those who took the water-trip, and at the Haileybury Club to those who elected to rest on land. In the evening an informal "smoker" was held at the Club, Hon. Dr. Pyne, Minister of Education, presiding; and a "volunteer" programme of surprising variety and excellence, comprising recitations, songs and speeches from hosts and guests alike, was given with great *éclat*.

[SECRETARY'S NOTE.—On such occasions, when no one hesitates or refuses to make his contribution to the general entertainment, every one has the right to feel that he may thus unbend and rejuvenate, without being pictured in that attitude for permanent reference. It has, therefore, been for many years the unwritten law of the Institute that the speeches and proceedings of its banquets shall not be reported in the *Transactions*. Especially on this occasion, it would be unfair to print as deliberate professional opinions the remarks made by sundry members of the Institute concerning the mineral riches of the Cobalt district and the rapidly developing wealth of forests and farms to the north and west of it. On the other hand, it would be unfair not to hint, at least, the nature of their utterances; and in these days of terror, nobody would willingly be "unfair!" Consequently, I take the liberty of saying that all the members of the Institute who spoke that night upon that theme emphasized the surprise and admiration with which they had inspected the Cobalt mines, and their confident expectation of the favorable future development of this uniquely rich field.—R. W. R.]

*Lake Temagami.*

On Saturday, July 27, the special train left Haileybury for Temagami, about 36 miles to the south. Near the Temagami station, the large outcrop of a deposit of iron-ore, not yet developed, was inspected with interest. In the afternoon, the steamer *Belle of Temagami*, of the O'Connor Steamboat Co., conveyed the party through the lovely archipelago, or chain of lakes and islands, a part of which is known as Lake Temagami. Some of them spent the night at the Temagami Inn, a picturesque rustic hotel, built of logs, on an island about 12 miles from the railway-station; the majority continued to Lady Evelyn lake, and spent Sunday at the Lady Evelyn Hotel. All returned Sunday evening to the special train.

The following account of this region is substantially taken from a "folder" issued by the Temagami Navigation Co.:

The "Temagami Forest Reserve," in New Ontario, is under control of the Ontario Government, and covers an area of some 1,400,000 acres. In the heart of this Reserve lies Lake Temagami (Indian name for "Deep Water"), surrounded on all sides by innumerable smaller lakes, all connected by rivers, streams and falls, forming a perfect network of unquestionably the finest canoeing- and camping-district in America. Lake Temagami contains some 1,400 islands, and all the adjoining lakes are dotted with many beautiful islands, forming ideal camping-grounds for all lovers of outdoor life.

Temagami station, on the northeast arm of the lake, is the entrance-point to this now famous tourist district. Lying as it does some 300 miles to the north of Toronto, Ontario, and 70 miles north from North Bay, it can now be reached by through trains, with Pullmans, leaving Toronto every evening and reaching Temagami early next morning. Some 20 miles to the north of Temagami station is Latchford, on the Montreal river, and 10 miles more brings one to the much-talked-of town of Cobalt (the "Silver City").

The Temiskaming & Northern Ontario Railway, or the "People's Railroad," as it is frequently called, was built and is now operated by a commission appointed by the Ontario Government. It is over this line that one travels from North Bay (the junction-point of the Grand Trunk Railway System and the Canadian Pacific Railway) into the New Ontario district; its lands laden, as they are proving to be, with mineral wealth and timber, and its primeval forests the haunts of big game.

The altitude of Lake Temagami is over 1,000 ft. above sea-level. The weather in the months of July, August and September, during the daytime, is warm and balmy, with little rain, and the nights are pleasantly cool for sleeping.

A number of camps are established at which accommodation can be had by applying in advance; but for those who are not able or do not care to rough it, there are the three hotels—the Renocco, at Temagami station; the Temagami Inn, on Temagami Island, near the center of the lake; and the Lady Evelyn Hotel, on Deer Island, at the northern end of the lake.

Besides the hotels, some boarding-houses have been established. At each of

these places a considerable number of guests can be accommodated. Cochrane's Camp, in the south arm, and the Keewaydin Camp, on Devil's Island, are primarily boys' camps, but provision has been made for receiving adults, upon special application, accompanied with satisfactory references.

### *Sudbury.*

Monday morning, July 29, the train arrived at Sudbury, where it was met by the Local Committee (the names of the members of which have been already given).

The smelting-works of the Canadian Copper Co. at Copper Cliff, where the party was received and guided by Messrs. A. P. Turner, President, D. H. Browne, metallurgist, and other officials of the company, were first visited; and in the afternoon the Creighton mine was inspected.

The following partial account of the Copper Cliff smelting-works of the Canadian Copper Co. has been condensed from an excellent paper by David H. Browne, the metallurgist of the company, published in the *Canadian Mining Journal*, Aug. 1, 1907:

These works, in their present condition, practically date from 1904, when the construction of a system of dams was begun at the High Falls of the Spanish river, about 25 miles from Copper Cliff, for the purpose of utilizing the water-power by electric transmission.

The power-house at High Falls is a concrete and brick building 106 ft. long and 55 ft. wide in the main, with an extension along one side 24 ft. wide containing the transformers and a wing 35 ft. square at one end containing a store-house and heating-plant. In this building provision is made for four penstocks 9 ft. in diameter, through which water enters to the turbines at a maximum speed of 7.2 ft. per second. Two turbines are at present in operation, and a third will be installed during the summer of 1907. These turbines, made by the I. P. Morris Co., of Phila., are designed for a maximum of 3,350 h.p. each. Direct-connected with each turbine is a 2,000-kw. generator, made by the Crocker, Wheeler Co.

The effective head of water is 85 ft., and the speed of the turbines and generators is 375 rev. per min. These generators produce 2,000 kw. current at 2,400 volts, 3-phase, and 25 cycles. Space is provided in the power-house for four such units, two of which were put in operation in February, 1906, and the third is at present under construction, leaving the fourth for future installation. When these generators were completed one was tested against the other by reversing the direction of rotation of the second and using it for a time as a turbine pump operating against the full head of water. In this way each machine was tested under varying brake-loads.

Two groups of three transformers are at present installed in the transformer-chamber behind the switchboard. These raise the pressure to 35,000 volts, at which tension it passes through the tower to the transmission line.

This line follows the Soo branch of the C. P. Railway, on a private right of way, and, owing to the necessary curves, is about 29 miles in length. It consists

of two 3-phase circuits of No. 1 wire, supported on a cross-arm on and between two poles. But one line is in operation at a time, provision being made for throwing the load from one to the other line in case of accident or repair. The insulators were tested at the start at 70,000 volts, and the transmission has given no trouble, except in two or three cases when the insulators have been accidentally or maliciously broken.

At Copper Cliff the line enters the sub-station, a concrete building 203 ft. by 100 ft., and is there stepped down to a proper voltage for the various electric motors. In this sub-station are installed three Nordberg radial-valve blowing-engines, while a fourth similar engine is being constructed at present. These engines are rope-driven by Allis-Chalmers-Bullock induction-motors of 600 h.p. working at 2,200 volts. These motors are arranged to work at three speeds, so that the volume of air delivered to the furnace is under control. The engines are duplex, 42 in. stroke, 70 in. piston-diameter, and deliver 320 cu. ft. of free air per revolution. The blast for the Bessemer converters is furnished by a Nordberg blowing-engine, rope-driven by an Allis-Chalmers-Bullock 500-h.p. induction-motor running at a constant speed of 375 rev. per min. This blower is 36 in. stroke, 40 in. in diameter, duplex, and runs at 100 rev. per min., delivering 12,600 cu. ft. of free air per min. at a pressure of 12 lb.

A 100-lb. air-compressor, made by the Laidlaw-Dunn-Gordon Co., with 25 in. stroke, 15 in. in diameter on the high-pressure, and 24 in. on the low-pressure cylinder, direct-connected to an Allis-Chalmers-Bullock induction-motor of 300 h.p., running 125 rev. per min. at 2,200 volts, serves for running drills, and other mechanical work. The motive power for the electric locomotives which take the trains of ore from the bins to the furnaces is furnished by one 40-kw. motor-generator set, which takes 550 volts, 40 amperes, alternating current, and delivers 250 volts, 100 amperes, direct current.

The alternating-current arc-lighting system used for street lamps is supplied by a 75-kw. frequency-changer set, in which the 25-cycle current from the transformers is changed to 60 cycles, as required by the arc lamps.

The blast from the three Nordberg air-compressors is carried through 36-in. pipes on an overhead system of supports to the furnace-building, which adjoins the sub-station. The furnace-building is 357 ft. long and 85 ft. wide. It covers at present three cupola furnaces, four converter-stands, and the relining-platform, but these converter-stands and the lining-machinery are in this building merely as a temporary expedient during the erection of the main converter-building. The furnace-building is designed to cover five cupolas, of which two have been in operation since July, 1904, and the third has been in blast since April, 1906, and two more are under construction. These cupolas stand in a row down the center of the building, having on one side two standard-gauge tracks for the disposal of furnace-slag, and on the other side a 32-ft. crane-span, on which two 50-ton cranes attend to the handling of furnace-matte to the converters and of Bessemer matte from the converters to the casting-molds.

The platform on which the settlers stand is 10 ft. above the floor of the smelter-building. On this rise the concrete bases of the furnaces, so that the hearth-plates of the furnaces are 6 ft. 6 in. above the tapping-platform. The furnaces are 50 in. by 204 in. at the tuyeres, and consist of two tiers of water-jackets, the lower or tuyere-jackets being 8 ft. 6 in. and the upper jackets 6 ft. in height. The total height from the lower floor of the furnace-building to the charging-floor is 35 ft., and the total jacket-height of the furnaces is 14 ft. 6 in.

Each of the tuyere-jackets contains four 8-in. tuyeres, which are bushed down to 4 in. The side tap is notched out of one of the middle tuyere-jackets on the crane side, and is filled with a water-cooled cast-iron side-tap jacket 10 by 24 in.

The furnace-slag flows off at the back of the settler into cast-iron slag-pots, each holding 22 tons. These slag-pots are made in sections, with four side-pieces and a separate bottom-piece. The train of three slag-pots is handled by a yard-locomotive, and poured over the slag-dump.

Matte from the settlers is tapped as required into cast-steel ladles 5 ft. high and 5 ft. in diameter. This is picked up by the electric crane and poured into the converters.

Four converter-stands are provided, and three are in use all the time. The shells are 7 ft. by 10 ft. 6 in. inside, and revolve in tread-rings 7 ft. 8 in. in diameter.

It is a curious point that copper-nickel behaves as one metal in the converter, and that the ratio of elimination of sulphur and iron in these mattes has exactly the same relation to the amount of copper-nickel present as the elimination of these elements in ordinary copper work has to the amount of copper present. The matte contains about 80 per cent. of copper-nickel.

The charges are accurately weighed before leaving the ore-bins, and the amount of flux is adjusted to the ore under treatment. Some ores, such as Creighton, require silica; others, as Crean Hill, sometimes require lime; in each case the endeavor is to produce a fluid slag which shall carry as little copper-nickel as possible. Slag from the converters, as well as all scrap and cleanings from the cupolas, is returned to the ore-bins. These bins, 700 ft. long and 35 ft. wide, are parallel with the furnace-building, and 200 ft. behind it. The roasted ore from the roast-yard, green ore from the mines, slag and scrap from the furnaces, coal and coke, quartz, clay and limestone, are all delivered on the upper tracks of the ore-bins, 35 ft. above the charging-floor.

The steam power-house, formerly used for the (then smaller) works, and now held in reserve, against any interruption of the electric power-system, is a brick building, 156 by 101 ft., situated about 150 ft. north of the furnace-building. It contains four 400-h.p. Aultman-Taylor boilers (fed with water previously treated with alkali, to neutralize its sulphuric acid); boiler and fire-pumps; a steam compound blowing-engine for the converters (Nordberg, Milwaukee, high-pressure cylinder, 15 by 42 in., low-pressure, 30 by 42 in., air-cylinders, 40 by 42 in., delivery, 10,000 cu. ft. free air at 12 lb. or 120 cu. ft. per rev.); also, to blow two furnaces, two cross-compound engines (Nordberg, dimensions and work of each, as to the items named above, 13 by 42 in., 26 by 42 in., 57 by 42 in., 20,000 cu. ft. air per min. at 45 oz. pressure, or 236 cu. ft. per rev.); also, steam-engines and dynamos for electric power; electric-lighting plant, etc. All this machinery, though valuable as a reserve, would not be adequate to run the works in case of break-down of the electric-transmission line from High Falls, because the works have been so greatly enlarged and the new construction involves much electric machinery, for which steam-power could not be substituted at a moment's notice.

The chemical laboratory, recently completed, is a one-story concrete and brick building, 35 by 80 ft. in size, with basement. The latter contains rooms for the storage of acids and glassware, special research-work, photographic work (dark), etc.; also, a Sturtevant fan, drawing cold air through a steam coil and distributing warm air through the building, and a suction fan, drawing the gases from the hood in the laboratory overhead and discharging them into a chimney. The main floor contains a main work-room, 41 ft. 3 in. by 21 ft. 6 in., and open, without ceiling, to the roof. At each end, a hall connects with special rooms: at one end, with the assay- and the sulphuretted-hydrogen-room; at the other, with the balance-room and the office; and above each of these halls a ventilating flue, connected with an electric fan, gathers and discharges into the outer air the gases which may have collected under the peak of the roof.

The arrangements of tables, hoods, etc., for laboratory work, represent the latest improvements in these particulars. A feature of special interest is the supply from electrically heated plates of all heat for evaporation, etc. These plates can be made at will to produce either of three temperatures: the lowest, just below the boiling-point of water, for slow evaporation; the next higher, for boiling ordinary solutions; and the highest, for driving off the last trace of sulphuric acid, or for baking residues, silica, etc.

A striking illustration of the completeness of this laboratory, and the desire of the company to employ scientific aid, not only for the promotion of technical economy but also for the welfare of its workmen, is furnished by a room (not specially mentioned in Mr. Browne's paper, yet highly deserving of mention), in which bacteriological and sanitary researches are conducted, with special reference to the potable waters of the region, and the protection of its inhabitants against typhoid fever, etc. This is regarded, not merely as a philanthropic undertaking, but also as a wise business precaution. The health of operatives is an all-important matter; and it is in such districts, suddenly populated, that the original purity of surface-waters is most likely to be impaired, with well-nigh pestilential consequences.

In addition to the plant above outlined, a new building, to contain ten Bessemer converters, is under construction. Mr. Browne's paper gives the particulars of this enlargement, and of the process of smelting, etc., as it will be conducted after the plant shall have been thus perfected.

The ore-supply comes from the Creighton and the Crean Hill mines. The former is the largest body of niccoliferous pyrrhotite ever opened in the Sudbury district. It is worked as an oval open pit, now about 160 ft. deep, and 225 ft. wide from hanging- to foot-wall. An incline in the foot-wall rock is connected by a short cross-cut with the bottom of the pit; and 13 tracks, radiating from the mouth of this cross-cut, serve to convey the ore, broken in steps on the sides of the pit, to the incline and the surface. A new shaft, 330 ft. west of the old one, is expected to double the producing-capacity of the mine. Within the past year, electricity has taken the place of steam for all the surface-machinery at this mine. Even the air-compressors driving the rock-drills are themselves driven by electricity.

The Crean Hill mine, opened during the past year, is not yet thoroughly developed. The ore seems to occur in veins from 50 to 80 ft. wide; and, containing a considerable proportion of pentlandite (iron-nickel sulphide), as well as a gangue of soapstone and greenstone, it requires a different treatment from that of the massive ores of the Creighton.

In the evening, a complimentary banquet, tendered to the Institute by the citizens of Sudbury, took place in Lennon's Opera House. The room was beautifully decorated with flags, bunting and electric lights; an orchestra on the stage discoursed appropriate music; Hon. L. O'Connor, Mayor of Sudbury, presided; and, after the generous provision made for the physical man had been enjoyed, a similarly abundant "feast" and "flow" of higher enjoyment was furnished by the following toasts: "The King"; "The President of the United States"; "The Dominion and Provincial Parliaments" (re-



sponded to by Hon. Dr. Pyne, Ontario Minister of Education, and Mr. C. N. Smith, member of the Ontario Legislative Assembly); "The American Institute of Mining Engineers" (responded to by Dr. R. W. Raymond, Secretary, Prof. W. P. Blake, past Vice-President, Dr. Fritz Cremer and M. Maurice Chatard, foreign guests from Germany and France, Professor William Kent, and Messrs. E. S. Hutchinson and William L. Saunders, members of the Institute); "The Canadian Institute of Mining Engineers" (responded to by Maj. R. G. Leckie, first President, and Mr. Eugene Coste, now President, of that Society); "The Mining Industries" (responded to by Messrs. H. W. Hixon, D. H. Browne, and Mr. Seeley—the last of whom spoke particularly of the Canadian iron-ore deposits, and also by Mr. H. J. Carnegie Williams, manager of the historic Bruce copper-mine on Lake Huron, who cordially invited members to visit that place and see what was being done to revive its commercial importance); and "The Prospector," responded to by Mr. James Stogie.

Mayor O'Connor and Minister Frank Cochrane also made felicitous addresses; and the company broke up long after midnight, with a feeling of happy satiety.

### *Moose Mountain.*

On Tuesday, July 30, the party visited the Moose Mountain iron-mine, where the great deposit of iron-ore was inspected, and a sumptuous "camp-dinner," provided by the Moose Mountain Iron Mining Co., was heartily appreciated.

The following notes on this mine are taken from the Programme of the Toronto Local Committee:

### *The Moose Mountain Iron-Mine.*

A railway, a branch of the Canadian Northern, has recently been completed from the main line of the Canadian Pacific a few miles east of Sudbury to the Township of Hutton, in which the Moose Mountain iron-mine is situated. Moose Mountain is about twenty-five miles north of Sudbury. Ore can now be shipped by rail from the mine. The Canadian Northern, a part of the Sudbury to Toronto branch, is in course of construction to the shore of the Georgian bay, which will give direct connection between the mine and Lake Huron. The

Moose Mountain ore, when the railway is completed, can be laid down on Lake Huron by a shorter rail haul than the Minnesota mines have to Lake Superior. The water-route to lower lake ports will be considerably shorter than that from Lake Superior ports and the navigation of the Sault Ste. Marie locks will be avoided.

That part of Ontario which embraces Sudbury and Cobalt contains the greatest known deposits of two out of the three magnetic elements, nickel and cobalt. Moose Mountain illustrates that the third magnetic element, iron, is found here in important quantity. Numerous iron-ranges occur in Ontario, among which may be mentioned, from east to west, Boston, Temagami, Hutton, Michipicoten, Animikie, Nipigon, Mattawin, and Atikokan. Most of these ranges are similar, geologically, to the Vermilion range of Minnesota. Little work has been done on these ranges compared with what was required to prove the ore-bodies on the United States side of Lake Superior, in Michigan and Minnesota. When the Ontario ranges are properly prospected, by means of diamond-drills and in other ways, it is confidently believed that many ore-bodies will be discovered. The three most important iron-mines, so far discovered in northern and western Ontario, had surface exposures of ore. The Helen mine of the Michipicoten range on Lake Superior has been a shipper for some years. Moose Mountain, north of Sudbury, and a deposit on the Atikokan range west of Port Arthur, are now ready to begin shipping. In southeastern Ontario, where the iron-deposits are similar to those of northern New York and New Jersey, mines have been worked at various times, and it would seem that there is an important field here for the magnetic concentration of iron-ore, similar to what is being done in New York State. The Mineral Range Company in Hastings county is shipping a high-grade magnetite to some of the Ontario furnaces.

The Moose Mountain iron-deposit occurs in rocks of Keewatin age, the oldest series of rocks known in this part of the continent. The Keewatin is essentially an igneous complex, the predominant rocks being greenstones. The deposit or deposits at Moose Mountain may be briefly described as follows: On Hill No. 1 there is an exposure of a lens of magnetite 800 ft. by 100 ft. to 150 ft. The ore has been proved in two

drill-holes 257 and 400 ft. in length, run at angles of 45° and 60°, respectively. This deposit is being worked by a cut which is 75 ft. lower than the top of the hill. In line with the larger axis of the lens, W. by N. one-half mile, another large ore-body has recently been found 600 ft. by 50 ft. in size. East by south from No. 1, one-quarter mile, another promising lens is being opened up.

*Analyses of Iron-Ores From the Hutton Township Ranges.*

No.		Per Cent. Iron.	Per Cent. Sulphur.	Per Cent. Phosphorus.	Titanium
1	Eugene Coste's sample, . . .	51.45	.001	.058	None.
	Prof. Coleman's report, . . .	62.64	.056	.011	"
2	Eugene Coste's sample, . . .	55.45	.010	.011	"
	Prof. Coleman's report, . . .	59.12	.08	.016	"
2	Extension, E. Coste's sample, . . .	44.54	.020	.037	"
3	Eugene Coste's sample, . . .	59.75	.013	.072	"
	D. D. Mann's sample (Heys' assay), . . .	55.75	None.	.001	"
	D. D. Mann's sample (Hersey's assay), . . .	53.07	.100	.014	"
4	Prof. Coleman's report, . . .	46.08	.06	.094	"
4(1)	E. Coste's sample, . . .	42.76	.015	.036	"
4(2)	E. Coste's sample, . . .	55.24	.015	.055	"
4(3)	E. Coste's sample, . . .	44.19	.002	.011	"
5	E. Coste's sample, . . .	31.70	.026	.051	"
6	E. Coste's sample, . . .	54.30	None.	.025	"

Sixteen miles north of Moose Mountain a similar iron-range is found at Burwash lake.

*The Vermilion River Placers.*

During Tuesday afternoon, on the return to Sudbury, the train made a brief stop, permitting a hasty inspection of a small experimental operation in washing the auriferous sands and gravels of the Vermilion river. Gold has been found over a large area along this stream; and no doubt it will prove possible to extract the metal with profit by modern methods at favorable points. Several of the visitors on this occasion satisfied themselves of its presence by panning it out from the crude material for themselves. Others were less successful; but it is not everybody who can handle a pan!

Mr. Robert H. Ahn, the director of the operations inspected, who received the party with much courtesy, writes that he has since completed some test-runs, which indicate that he can recover 20 cents per cu. yd. in gold, besides being able to sell at a good price at least half of his washed gravel. These figures are certainly encouraging; and we all hope that Mr. Ahn will achieve the success he deserves.

*Conclusion.*

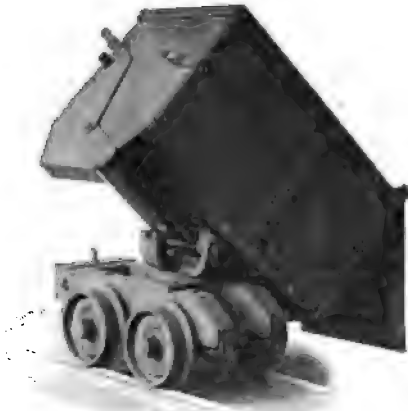
The train arrived at Toronto on Wednesday, July 30. Many of the tourists, however, left it *en route*, to enjoy the offered hospitality of Canadian friends, or to explore further for themselves the wonderful lake- and forest-region of Ontario.

Official letters of thanks have been sent to an almost innumerable host of the generous entertainers of the Institute; and a liberal subscription, received from members of the excursion party, has been expended in the preparation of a handsome gold watch-fob (similar to those illustrated on p. xc of Vol. XXXVII. of the *Transactions*) which has been sent as a souvenir to Prof. W. G. Miller, the Chairman of the Toronto Local Committee; also, a large engrossed certificate of grateful acknowledgments, to be duly signed by the officers of the Institute and sent to the Department of Mines, Lands and Forests of the Province of Ontario, the head of which, Hon. Frank Cochrane, so greatly contributed, both officially and personally, to the complete social and professional success of the meeting.



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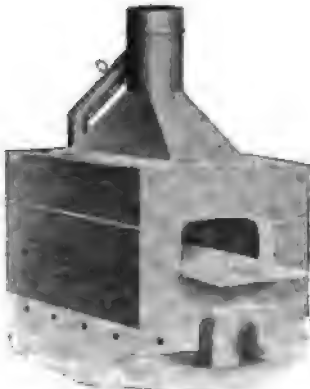
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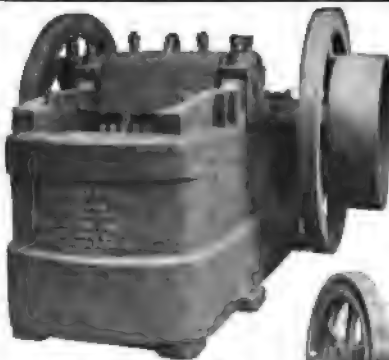
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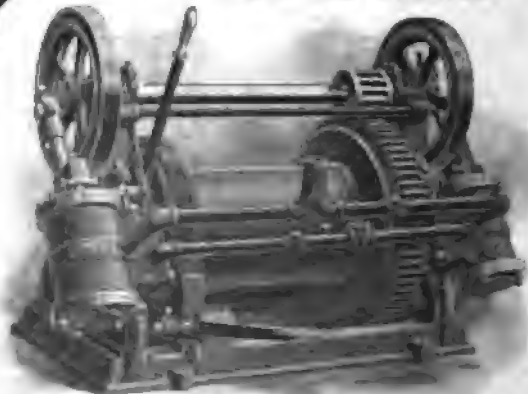
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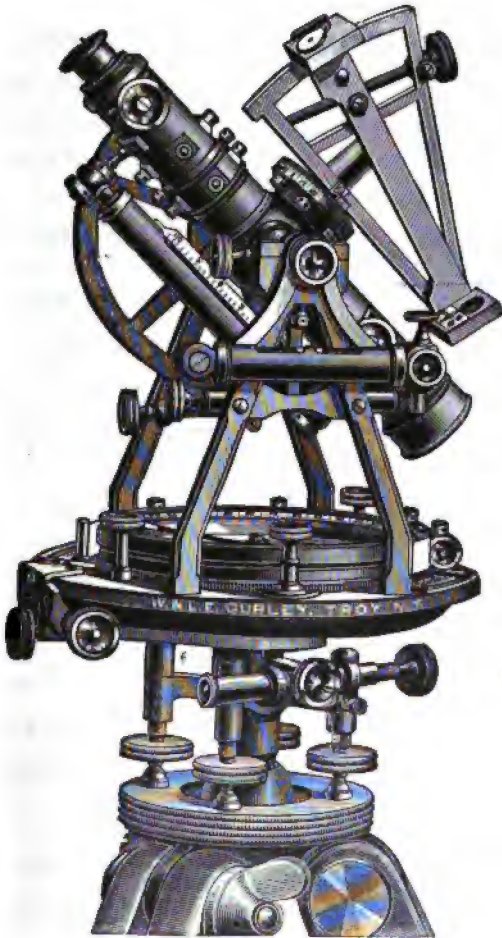
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<p><b>RICHARDS, ROBERT H.,</b> Ore Dressing, Massachusetts Institute of Technology <b>BOSTON,</b> <b>MASS.</b></p>	<p><b>SPILSBURY, E. GYBBON,</b> Consulting, Civil, Mining and Metallurgical Engineer, 45 Broadway, <b>NEW YORK.</b> Cable Address: "Spilroe," New York.</p>
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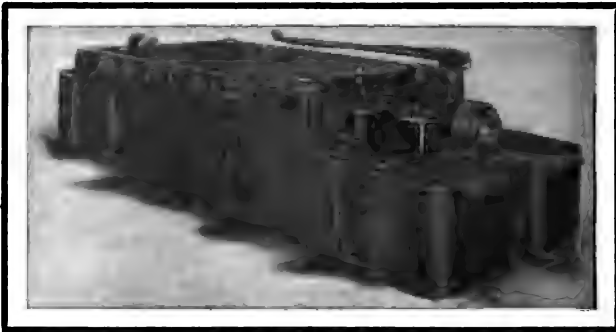
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No. 18.

NOVEMBER.

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OF THE

# American Institute of Mining Engineers.



PUBLISHED BY THE AMERICAN INSTITUTE OF MINING ENGINEERS

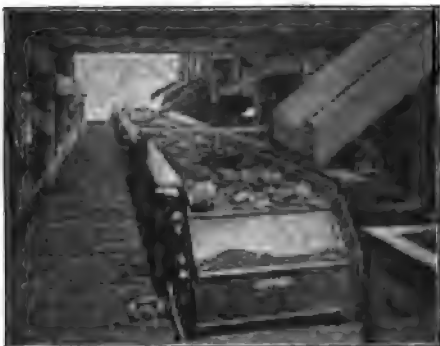
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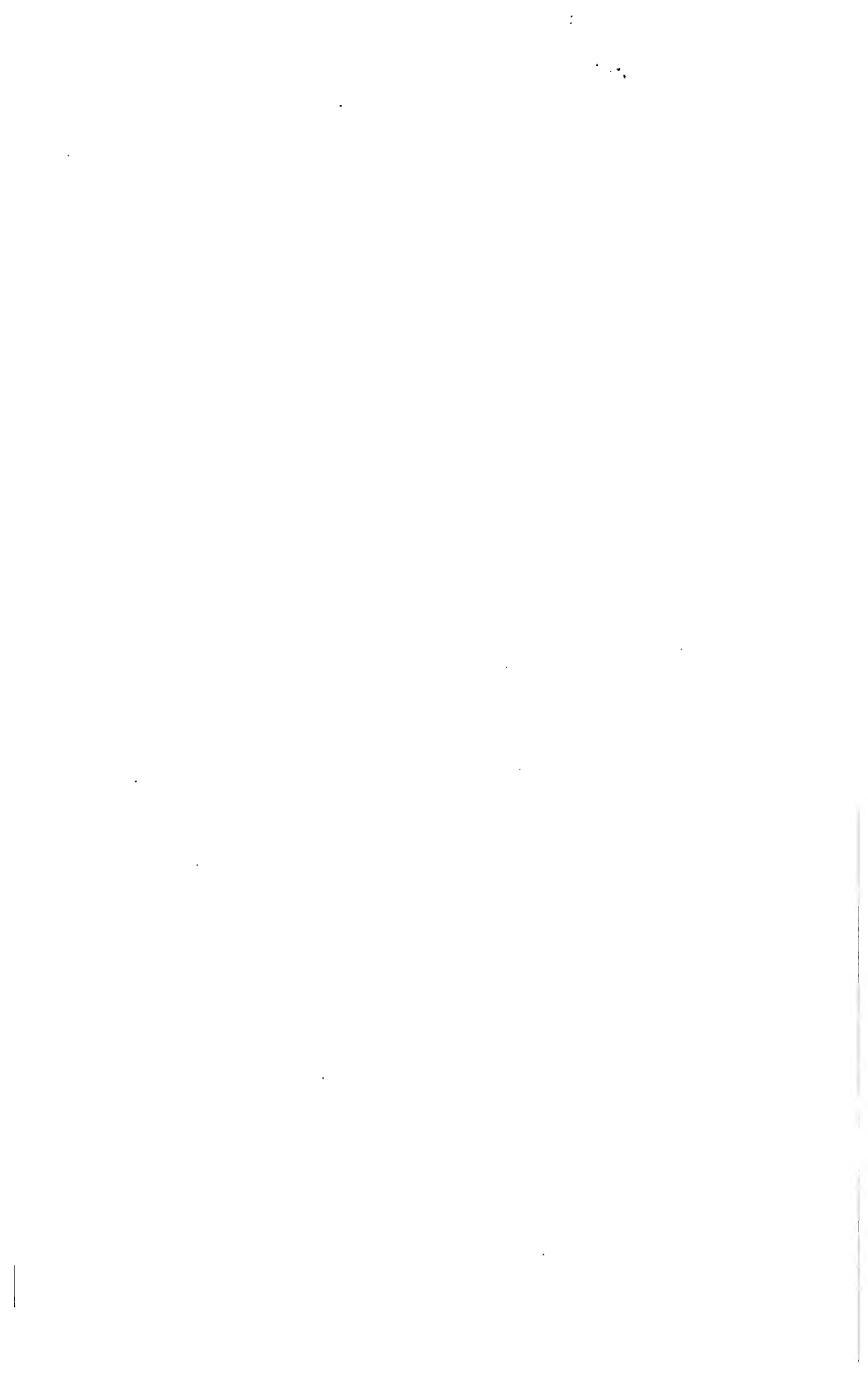
## NEW YORK MEETING, FEBRUARY, 1908.

The Ninety-fourth Meeting of the INSTITUTE, for the reading and discussion of papers, will be held at New York City, beginning Tuesday evening, February 18, 1908. Further particulars concerning this meeting will be given in *Bi-Monthly Bulletin* No. 19, for January, 1908, or, if necessary, by a separate circular from this office.

R. W. RAYMOND,

*Secretary.*

NOVEMBER 20, 1907.



Aug. 14, 1916.

Bequest of

Erasmus Darwin Leavitt.

# BI-MONTHLY BULLETIN

OF THE

## AMERICAN INSTITUTE OF MINING ENGINEERS.

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No. 18

NOVEMBER

1907

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PUBLISHED BY THE AMERICAN INSTITUTE OF MINING ENGINEERS

At S-W. Cor. of Seventh and Cherry Streets,

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Editorial Office at 29 West 39th St., New York, N. Y.

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*Subscription (including postage), \$10 per annum; to members of the Institute, public libraries, educational institutions and technical societies, \$5 per annum.*

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# TABLE OF CONTENTS.

## SECTION I. INSTITUTE ANNOUNCEMENTS.

	PAGE
Bi-Monthly Bulletin, . . . . .	iii
List of Officers for the Year Ending February, 1908, . . . . .	iv
Collective Index of the <i>Transactions</i> , Vols. I. to XXXV., inclusive, . . . . .	v
Special Notice, Library, . . . . .	vi
Special Notice, Reception Room, . . . . .	vii
Library, . . . . .	viii
Membership, . . . . .	xvii
Candidates for Membership, . . . . .	xviii
Change of Address of Members, . . . . .	xxi
Address Wanted, . . . . .	xxxi

## SECTION II. TECHNICAL PAPERS.

No. 1. HJALMAR SJÖGREN. The Geological Relations of the Scandinavian Iron-Ores, . . . . .	877
No. 2. CHARLES CATLETT. Quantitative Field-Test for Magnesia in Cement-Rock and Limestone, . . . . .	947
No. 3. THOMAS L. WATSON. Geology of the Virginia Barite-Deposits, . . . . .	953
No. 4. LUTHER WAGONER. The Presence of Gold and Silver in Deep-Sea Dredgings, . . . . .	977
No. 5. W. R. INGALLS. Chronology of Lead-Mining in the United States, . . . . .	979
No. 6. WILLIAM L. SAUNDERS. The Electric-Air Drill, . . . . .	991
No. 7. JAMES DOUGLAS. Secrecy in the Arts, . . . . .	1001
No. 8. INDEX OF TITLES AND AUTHORS OF THE <i>Bi-Monthly Bulletin</i> FOR THE YEAR 1907, . . . . .	1019

## ERRATA.

Correction to *Bi-Monthly Bulletin*, No. 17, September, 1907 :

Page 800, Fig. 5, title, should read "Press of Zwoyer Fuel Company built for Bankhead Mines, Ltd., Bankhead, Alberta, Can."

## BI-MONTHLY BULLETIN.

### SECTION I.—INSTITUTE ANNOUNCEMENTS.

This section contains announcements of general interest to the members of the Institute, but not always of sufficient permanent value to warrant republication in the volumes of the *Transactions*.

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### SECTION II.—TECHNICAL PAPERS AND DISCUSSIONS.

[The American Institute of Mining Engineers does not assume responsibility for any statement of fact or opinion advanced in its papers or discussions.]

A detailed list of the papers contained in this section is given in the Table of Contents. They have been so printed and arranged (blank pages being left when necessary) that they can be separately removed for classified filing, or other independent use.

A small stock of separate pamphlets, duplicating the technical papers given in Section II. of this Bulletin, is reserved for those who desire extra copies of any single paper.

Comments or criticisms upon all papers given in this section, whether private corrections of typographical or other errors or communications for publication as "Discussions," or independent papers on the same or a related subject, are earnestly invited.

All communications concerning the contents of this Bulletin should be addressed to Dr. Joseph Struthers, Assistant Secretary and Editor, 29 W. 39th St., New York City (Telephone number 4600 Bryant).



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\* SECRETARY'S NOTE.—The Council is the professional body, having charge of the election of members, the holding of meetings (except business meetings), and the publication of papers, proceedings, etc. The Board of Directors is the body legally responsible for the business management of the Corporation, and is therefore, for convenience, composed of members residing in New York.

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*Buy at once a copy of this Index, and also as many back-volumes of the Transactions as you can afford.* Every such purchase from the stock on hand is so much added to the income of the Institute. As far as possible, the money thus received will be devoted to maintaining and perfecting the Library, and making it useful to members in all parts of the world.

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**American Foundrymen's Association.**

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**Chemical Society of London.**

**Deutsche Chemische Gesellschaft.**

**The Foundry.**

**New Zealand Mines Record.**

**Queensland Government Mining Journal.**

**La Revue Universelle des Mines.**

**Mining and Scientific Press.** Vol. 52, no. 23 (June 5,  
1886); vol. 53, no. 3 (July 17, 1886).

**Société Chimique de Paris.**

**Société de L'Industrie Minerale.**

**Stahl und Eisen.**

**Tonindustrie Zeitung.**

**Zeitschrift für Anorganische Chemie.**

**Zeitschrift für Angewandte Chemie.**

Complete sets of the above publications are greatly needed,  
as none of them are duplicated in the library of the American  
Institute of Electrical Engineers or in that of the American So-  
ciety of Mechanical Engineers.

Please communicate on the above subject with R. W. Ray-  
mond, Chairman of the Library Committee, 29 W. 39th St.,  
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## **MEMBERS' PRIVATE RECEPTION ROOM.**

A separate room in the suite occupied by the American Institute of Mining Engineers on the ninth floor of the United Engineering Society Building, has been equipped with furniture and telephone extension for the use of members of the Institute who desire temporary private office accommodations.

In order that the benefit of this arrangement shall not be restricted to a few members only, the length of time of continued occupancy is limited, and applications will be considered in the order of their receipt. A small fee will be required for the use of this room.

## LIBRARY.

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The above rules apply to all persons except officers of the three Societies, personally known as such to the librarians.

The librarians are not permitted to lend to any person any catalogued pamphlet or volume, unless authorized in writing so to do by the Secretary or Chairman of the Library Committee of the Society to which the pamphlet or volume belongs.

Any person discovering a mutilation or defect in any book of the libraries is requested to report it to the librarian on duty.

## WANTS.

It is the earnest desire of the Library Committee to complete the files of the more important serial publications in the library of the American Institute of Mining Engineers, and for the furtherance of this wish, the co-operation of members and friends of the Institute is respectfully invited. A list of the volumes needed is given on page vi of this *Bulletin*.

## Accessions.

From September 1 to October 31, 1907.

**The American Metal Company, Limited.**

METALLGESELLSCHAFT AND THE METALLURGISCHE GESELLSCHAFT A-G. *Comparative Statistics of Lead, Copper, Spelter, Tin, Aluminium, Nickel, Quicksilver and Silver.* 13th annual issue. 4to. Frankfort-on-the-Main, 1907.

**American Institute of Mining Engineers.**

AMERICAN INSTITUTE OF MINING ENGINEERS. *General Alphabetical and Analytical Index to the Transactions*, Volumes 1 to 35. lxxix, 626 p. 8vo. New York, 1907. Price, \$5.00, cloth; \$6.00, half-morocco.

*Annuario della Industria Mineraria, Metallurgica e Chimica Italiana.* Anno 1. 12mo. Torino, 1907.

**Ashland Mining Office.**

*Supplement to the Fifth Anniversary Edition of the Oregon Journal*, Sept. 8, 1907. "The Coming of the White Man."

**Commissioner of Mines of the Transvaal.**

TRANSVAAL—SOUTH AFRICA—COMMISSIONER OF MINES. *Report of a Commission . . . to Inquire into the Use of Winding Ropes, Safety Catches and Appliances in Mine Shafts.* cxvii p. f°. Pretoria, 1907.

**Prof. William P. Blake.**

BLAKE, W. P. *Ceramics.* pp. 113–226 pl. 8vo. Paris, 1878.

——— *Report on Iron and Steel.* ix, 311 p. il. pl. 8vo. Washington, 1876.

HORNES, M. *Die Fossilen Mollusken des Tertiaer Beckens von Wien.* Vol. 2, nos. 11, 12–16, 19–20. f°. n. p., n. d.

**Prof. William P. Blake.**

KAISERLICH—KÖNIGLICHE GEOLOGISCHEN REICHSANSTALT.  
*Abhandlungen.* Vols. 1–3. f°. Wien, 1852, 1855,  
1856.

——— *Jahrbuch.* Years 1–3, 5–8, 10–15. 4to. Wien,  
1851–'66.

——— *General Register* to Years 1–10, 1850–'59.  
4to. Wien, 1863.

——— *Ansprache Gehalten am Schlusse des Ersten Decen-*  
*niums der.*, Nov. 22, 1859. 37 p. map. 8vo. Wien,  
1859.

*Mining Magazine* (New York). Vol. 5, no. 1; vol. 10, no. 5;  
2d ser., vol. 1, nos. 1–6. 8vo. New York, 1855,  
1858–'60.

*Mining Reporter.* Vol. 53, nos. 16, 25, 26; vol. 54, nos.  
1, 3, 5–21; vol. 55, nos. 17, 18, 26; vol. 56, nos. 5, 7,  
8, 10, 11. 4to. Denver, 1906–'07.

**P. Blakiston's Son & Company, Philadelphia.**

ALLEN, A. H. *Commercial Organic Analysis.* Edition 3.  
8 vols. in 4. 8vo. Philadelphia–London, 1898, 1905–  
'07. (Vol. 3, pts. 2–3, and vol. 4, ed. 2.)

[LIBRARIAN'S NOTE.—In the record of library accessions, p. xii of the Sep-  
tember *Bi-Monthly Bulletin*, Part 3 of Vol. II. was, by a typographical error,  
acknowledged as "Part 2."]

[SECRETARY'S NOTE.—In the September *Bi-Monthly Bulletin*, I noticed the  
contents of Part 3 of Vol. II. of this edition of Allen's comprehensive work.  
As I then said, the issue of this part completed the republication of the whole  
treatise in revised and modernized form. The publishers, having learned that  
the Institute library lacked the rest of the new edition, have now generously  
donated the preceding parts, completing the series of eight octavos.

The author's modification of his original distribution of topics has been fol-  
lowed in this edition. The present scheme is as follows:

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As now completed, this series of volumes, issued in their present revised form at intervals during the last ten years (the latest two in 1906 and 1907) is a worthy monument to its distinguished author, who died (in 1904) too early to finish his great work.

Prof. Allen was fortunate in his American revisers and editors, Dr. Henry Leffmann, Professor of Chemistry and Metallurgy in the Pennsylvania College of Dental Surgery and the Wagner Free Institute of Science at Philadelphia, and Dr. J. Merritt Matthews, Professor of Chemistry and Dyeing at the Philadelphia Textile School. Prof. Matthews, indeed, wholly re-wrote the material relating to the tannins, coloring matters and writing inks, which now constitutes Vol. III., Part 1, adding, at the same time, a large amount of later information. Thus, the important chapter on Tannins contains descriptions of new tannin-materials, and several new methods of analysis ; the chapter on Dyes and Coloring Matters has been rearranged, and nearly doubled in extent ; and the former classification has been remodeled, to meet the demands of progress in this most active branch of technological chemistry. Another feature of great value is the frequent tabulation of reactions and methods, which enables the reader, at a glance, to take a comprehensive survey, not otherwise to be gained without tedious labor.

It is impossible to claim for any such cyclopædic treatise as this that it is "up-to-date," if by "date" is meant *to-day*. That date changes daily, and in modern industrial science every day registers a new stage of progress. But an extensive work of this class, every part of which is "up to" its own date, and furnishes a complete and trustworthy picture of the history and state of its own art, is inestimably and permanently precious to every student, because it makes more ancient researches comparatively unnecessary. It is like a certified and warranted title to land—possessing which, the searcher has only to look for later transfers and liens. It is like an established monument, which subsequent surveys can safely take as a starting-point. And, in this respect, it becomes more useful as the years go on, and the inevitable labor of research increases in geometrical ratio. But, in order that it may serve this purpose, it must contain not only complete summaries of facts, but also adequate references to the original sources of its statements. This condition also has been satisfied, in the volumes before me, by abundant references to technical literature. It seems to me that such works will never be entirely superseded ; that they will continue to be indispensable long after they have ceased to be "up-to-date."—R. W. R.]

SMITH, E. F. *Electro-Analysis*. Ed. 4. viii, 386 p. il. 8vo. Philadelphia, 1907. Price, \$2.50, net.

[SECRETARY'S NOTE.—This new edition of Professor Smith's well-known manual contains important additions, chiefly with respect to the rapid precipitation



and separation of metals, the use of a mercury cathode with rotating anode, and the employment of a new two-compartment cell in the determination of cations and anions. The last of these subjects is particularly interesting and attractive. Chemists will be probably somewhat startled to learn that the estimation, for example, of barium and chlorine can be made in this way in an hour less, with superior neatness and accuracy.

In theory as well as in laboratory practice, the book is thoroughly up-to-date; and even a cursory examination of it suffices to show that it represents a notable advance in analytical methods and apparatus, of which no chemist can afford to remain ignorant.—R. W. R.]

### **Commissioner of Mines of Natal.**

SOUTH AFRICA—NATAL—MINES DEPARTMENT. *Report on the Mining Industry, 1906.* f°. Pietermaritzburg, 1907.

### **Karl Ellers.**

*Berg und Hüttenmannisches Zeitung.* Vol. 42, nos. 18–38, 40–48, 1903; vol. 43, nos. 1–19, 21–48, 50–52, and index, 1904. 4to. Leipzig, 1903–'04.

*Glückauf.* Vol. 40, index, 1904; vol. 41, nos. 1–13, 15, 17–45, 47–48, 51, and index, 1905; vol. 42, nos. 1–5, 7–8. 1906. 4to. Essen–Ruhr, 1904–'06.

### **El Oro Mining and Railway Company, Limited.**

EL ORO MINING AND RAILWAY COMPANY, LIMITED. *Directors' Report and Statement of Accounts for Year Ending June 30, 1907.* 4to. London, 1907.

### **Engineering and Mining Journal.**

FULTON, C. H. *A Manual of Fire Assaying.* xii, 178 p. il. 8vo. New York, 1907. Price, \$2.00.

[SECRETARY'S NOTE.—This latest manual, besides being "up-to-date," contains some new features, such as parts of the chapters on "Reduction and Oxidation Reactions," "Crucible Assay and Assay Slags," and "Cupellation," which outline scientifically the principles of assaying, and the chapter on "Errors in the Assay for Gold and Silver," in which Prof. Fulton says he has discussed the accuracy of the assay in greater detail than has been attempted heretofore. The book is pretty closely confined to assays for gold and silver only, the assay of tin, mercury, lead, bismuth and antimony being treated cursorily in less than ten pages, and that of copper being dismissed with the statement that the fire-assay of copper is practically no longer in use, except in part of the Lake Superior district. But within the sphere thus frankly limited, Prof. Fulton has treated his subject with great thoroughness and detail, and his familiarity with it, both as an instructor and as an operator and director, has enabled him to produce a work which will be useful to the technical student, as well as to the assayer in practice. The engravings are excellent; and there are adequate indexes of authors and topics.—R. W. R.]

**Far Eastern Review Company.**

*Far Eastern Review.* Vol. 3, nos. 10-12; vol. 4, no. 1.  
4to. New York, 1907.

**Rudolph Franke.**

*Sonder abdruck des hüttentechnischen Theiles der Mansfelder Festschrift zum X-ten deutschen Bergmannstage.* Bearbeitet von R. Franke. (Separate pamphlet, containing the technical metallurgical portion of the Mansfeld Memorial of the Tenth German Miners' Diet. Prepared by R. Franke.) 64 p. pl. 8vo. n. p. n. d.

[SECRETARY'S NOTE.—This beautifully printed and illustrated monograph, prepared by the competent hand of Metallurgical Inspector Franke, of Eisleben, gives a complete view of present practice in one of the leading copper-producing districts of the world—a district in which peculiar disadvantages and difficulties, both in mining and in metallurgy, have been overcome by exceptional technical skill. The Mansfeld deposits and the Mansfeld methods have been for more than a generation described and discussed by the authors of classic professional literature. It is supremely interesting and important to know their relation to modern conditions of science and industry; and this knowledge is furnished by Inspector Franke's exceedingly clear and thorough account.—R. W. R.]

**General Electric Company.**

GENERAL ELECTRIC COMPANY. *General Electrical Review*,  
Sept., 1907. 4to. Schenectady, 1907.

**Geological Commission of the Cape of Good Hope.**

CAPE OF GOOD HOPE—GEOLOGICAL COMMISSION. *Annual Report*, 11th. 8vo. Cape Town, 1907.

**Institution of Mining and Metallurgy, London.**

INSTITUTION OF MINING AND METALLURGY. *Bulletin* Nos.  
36, 37. 8vo. London, 1907.

**Iron and Steel Institute, London.**

BANNISTER, C. O. and LAMBERT, W. J. *Case-Hardening of Mild Steel.* 8 p. pl. 8vo. London, 1907.

BAUERMAN, H. *Erzberg of Eisenerz.* 12 p. pl. maps.  
8vo. London, 1907.

BERWERTH, F. *Steel and Meteoric Iron.* 12 p. 8vo. London, 1907.

CARULLA, F. J. R. *New Blue-Black Iron Paint as a Protective Covering.* 4 p. 8vo. London, 1907.

DEMOZAY, L. *Hardening of Steel.* 36 p. il. pl. 8vo.  
London, 1907.

**Iron and Steel Institute, London.**

EHRENWERTH, J. VON. *Determination of the Total Quantity of Blast-Furnace Gas for a Given Make and its Calorific Value.* 4 p. 8vo. London, 1907.

JÜPTNER, H. VON. *Application of the Laws of Physical Chemistry in the Metallurgy of Iron.* 28 p. 8vo. London, 1907.

KESTRANEK, W. *Austrian Iron Industry During the Last Twenty-five Years.* 16 p. 8vo. London, 1907.

LONGMUIR, P. *Hardened Steels.* 8 p. pl. 8vo. London, 1907.

SCOTT, G. S. *Case-Hardening.* 19 p. il. 8vo. London, 1907.

STROMEYER, C. E. *Further Experiments on the Ageing of Mild Steel.* 23 p. pl. 8vo. London, 1907.

THWAITE, B. B. *Economic Distribution of Electric Power from Blast-Furnaces.* 12 p. il. 8vo. London, 1907.

**Charles Kirchhoff.**

ALLING, G. W. *Points for Buyers and Users of Tool Steel.* 224 p. il. 12mo. New York, 1903. Price, \$2.00.

[SECRETARY'S NOTE.—This excellent little manual has been before the public for several years, and has proved valuable to many who, not technically educated, are obliged in the course of business to pronounce judgment, at least by way of selection or rejection, upon steel tools or steel bars for tools. At the same time, such a hand-book is sure to contain many practical hints, which a theoretic training does not supply.

Mr. Alling writes with an adequate amount of scientific knowledge concerning modern processes and tests; but his style is adapted to the average business man, and the topics which he treats are eminently practical. The book is in two parts, the first of which, in eleven chapters, gives homely and timely advice to buyers of steel, telling them how to avoid the usual stumbling-blocks encountered by the inexperienced; when and why to use high-priced steel; how to recognize the best; what grades are suitable for special uses; how to regard nostrums and new methods, etc., etc. These chapters are full of anecdote, wit, and "hard sense," and will interest every reader. The second part contains fifteen chapters, giving hints as to the working of steel; instructions for the detection of imperfect steel; explanations of the occasional puzzling behavior, even of good steel; and general directions concerning the hardening and tempering of steel. There are numerous instructive illustrations, and a number of useful tables.—R. W. R.]

**Königliche Preussische Geologischen Landesanstalt und Bergakademie.**

KÖNIGLICHE PREUSSISCHE GEOLOGISCHEN LANDESANSTALT UND BERGAKADEMIE. *Jahrbuch.* Vol. 24. 4to. Berlin, 1907.

**Manchester Geological and Mining Society.**

MANCHESTER GEOLOGICAL AND MINING SOCIETY. *Transactions*. Vol. 28, pt. 18. Manchester, 1904.

**Ministerio de Colonizacion y Agricultura de Bolivia.**

D'ORBIGNY, ALCIDES. *Estudior Sobre la Geologia de Bolivia Traducidos por Victor E. Marchant*. xix, 104, ii p. maps. 12mo. La Paz, 1907.

**Minister of Mines of New Zealand.**

NEW ZEALAND MINISTER OF MINES. *Essays on Mineral Resources of New Zealand*. 297 p. 8vo. Wellington, 1907.

NEW ZEALAND MINES DEPARTMENT. *New Zealand Handbook*, 1906. 8vo. Wellington, 1906.

**F. Osmond.**

OSMOND, F. *Les Recherches de G. Cartaud sur Le Passage de L'État Liquide a L'État Solide*. p. 819-832.

Extrait de la *Revue de Métallurgie*, vol. iv., Sept., 1907.

**R. W. Raymond.**

MITSUI MINING COMPANY. *The Mining and Mechanical Enterprises of the Mitsui Firm*. 68, 2 p. il. map. 8vo. Tokyo, 1903.

**Royal Statistical Society.**

ROYAL STATISTICAL SOCIETY. *List of Members, 1906-'07*. 8vo. London, 1907.

**Scranton Engineers' Club.**

SCRANTON ENGINEERS' CLUB. *Directory*, 1907. 8vo. Scranton, 1907.

**Smithsonian Institution—U. S. National Museum.**

SMITHSONIAN INSTITUTION—U. S. NATIONAL MUSEUM. *Proceedings*. Vols. 10 and 11. 8vo. Washington, 1888, '89.

**Dr. Joseph Struthers.**

*Descriptive Catalogue of Economic Minerals of Nova Scotia, Canada*. 60 p. 8vo. Halifax, 1907.

*The Dominican Republic*, 1907. 93 p. 8vo. n. p., 1907.

IOWA GEOLOGICAL SURVEY. *Bulletin* no. 2. 8vo. Des Moines, 1905.

JAMESTOWN OFFICIAL PUBLICATION COMPANY. *Official Catalogue Jamestown Ter-Centennial Exposition*. 70 p. il. map. 8vo. Norfolk, 1907.

**Svenska Teknologforeningens.**

SVENSKA TEKNOLOGFORENINGENS. *Forteckning ofver . . .*  
*Ledamoter.* Mars, 1907. 8vo. Stockholm, 1907.

**U. S.—Coast and Geodetic Survey.**

U. S.—COAST AND GEODETIC SURVEY. *Annual Report*, 1878,  
1891-'95, 1897, 1899-1904. 4to. Washington, 1881,  
1892-1904.

**Vogel, Otto.**

VEREINS DEUTSCHER EISENHÜTTENLEUTE. *Jahrbuch für das*  
*Eisenhüttenwesen*, 1904. 8vo. Düsseldorf, 1907.

## MEMBERSHIP.

The following list comprises the names of those persons elected as members or associates, who accepted election during September and October, 1907:

## MEMBERS.

Samuel J. Alderman, . . . . .	Benton, Cal.
Lyndon K. Armstrong, . . . . .	Spokane, Wash.
Reginald H. T. Brook, . . . . .	Ballarat, Victoria, Aus.
Joseph Brown, . . . . .	Socorro, New Mex.
Donald F. Campbell, . . . . .	Baird P. O., Cal.
John A. Church, Jr., . . . . .	Guanajuato, Mex.
Raymond B. Crowell, . . . . .	Carson City, Nev.
Jack Cussons, . . . . .	Mineral, Va.
Aubrey P. Fellows, . . . . .	Joplin, Mo.
Thomas C. Groom, . . . . .	Cobar, N. S. W., Aus.
William A. Kissam, . . . . .	Manila, P. I.
John Francis Manning, . . . . .	Chicksan, Korea.
Robert McL. Moore, . . . . .	Kiandra, N. S. W., Aus.
Roy Webb Moore, . . . . .	Tucson, Ariz.
Millard K. Shaler, . . . . .	Lawrence, Kan.
Waldo Sheldon, . . . . .	Greenwich, Conn.
Alfred C. Sieboth, . . . . .	Florence, Ariz.
Tom R. Starkey, . . . . .	Punta Arenas, Chile, So. Am.
Henry Twynam, . . . . .	Cairns, N. Queensland, Aus.
Edward Watson, . . . . .	Akmolinsk, Siberia.
Edwin P. Williams, . . . . .	South Chicago, Ill.

## ASSOCIATE.

Walter R. Hodge, . . . . .	Mexico City, Mex.
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## NECROLOGY.

The deaths of the following members and associates have been reported to the Secretary's office during September and October, 1907:

Date of Election.	Name.	Date of Decease.
1897.	*Charles W. Benton, . . . . .	September 9, 1907.
1903.	*George V. Devinny, . . . . .	August 22, 1907.
1888.	*Charles J. Hillard, . . . . .	September 12, 1907.
1894.	*Louis Pelatan, . . . . .	— — —, 1907.
1904.	*George W. Rose, . . . . .	September 11, 1907.
1902.	*Gilbert C. Simpson, . . . . .	September —, 1907.

\* Member.

## CANDIDATES FOR MEMBERSHIP.

The following persons have been proposed for election as members or associates of the Institute during September and October, 1907. Their names are published for the information of members and associates, from whom the Committee on Membership earnestly invites confidential communications, favorable or unfavorable, concerning these candidates. A sufficient period (varying in the discretion of the Committee, according to the residence of the candidate) will be allowed for the reception of such communications, before any action upon these names by the Committee. After the lapse of this period, the Committee will recommend action by the Council, which has the power of final election. The names of candidates were formerly published in the various circulars of the Institute, issued from time to time to the members. Hereafter, these names will appear regularly in the *Bi-Monthly Bulletin*, each number of which will contain the names received since the issue of the preceding *Bulletin*.

### MEMBERS.

William Aplin, . . . . .	Cumberland, N. Queensland, Aus.
A. H. B. Arnold, . . . . .	Hazel Green, Wis.
Richard F. Böhler, . . . . .	Kapfenberg, Styria, Austria.
Clifford Douglass Caldwell, . . . . .	Pennington Gap, Va.
William Henry Goodchild, . . . . .	Finchley, Middlesex, England.
Adolph Julius Greit, . . . . .	New York, N. Y.
John Marriott Grice, . . . . .	Salinas, S. L. P., Mex.
William Gummere, . . . . .	Trenton, N. J.
D. F. Haley, . . . . .	West Gore, N. S., Can.
Harry Bradford Tanered Hawkins, . . . . .	Ballydehob, Ireland.
Donnel Foster Hewett, . . . . .	Pittsburg, Pa.
Señor J. Hohagen, . . . . .	Potosi, Bolivia, S. America.
Elmer A. Holbrook, . . . . .	Hedley, B. C., Can.
Reginald Edwin Hore, . . . . .	Toronto, Can.
Archibald J. Hunt, . . . . .	Mapimi, Durango, Mex.
Thatcher Rodney Hunt, . . . . .	Iron Mountain, Cal.
Kenji Kaishima, . . . . .	Tokyo, Japan.
Shun Tet Kong, . . . . .	Hunan, China.
Robert Balfour Law, . . . . .	Glasgow, Scotland.
Willis Lawrence, . . . . .	Yuma, Ariz.
William Arthur Laycock, . . . . .	Haileybury, Ontario, Can.

John Edward Leibfried, . . . . .	Chicago, Ill.
Frank Arthur Linforth, . . . . .	Butte, Mont.
Julius A. Lewisohn, . . . . .	New York, N. Y.
Frederick Fleming McIntosh, . . . . .	Glen Osborne, Pa.
Alexander Tertius Carson McMaster, . . . . .	Toronto, Can.
Alfred Marquis Mackilligin, . . . . .	Tarkwa, West Africa.
Robert Marsh, Jr., . . . . .	McGill, Nev.
Robert Lanphier Martin, Jr., . . . . .	Pittsburg, Pa.
Ellwood Vandiver Matlack, . . . . .	St. Louis, Mo.
Martin Munroe, . . . . .	Calcutta, India.
William George Norrie, . . . . .	Rosslund, B. C., Can.
De Villiers Gurling Pritchard, . . . . .	Cape Colony, South Africa.
Francis Rogers Pyne, . . . . .	Great Falls, Mont.
William Ramsay, . . . . .	Black Mountain, Va.
Edwin Colville Reeder, . . . . .	Copper Cliff, Ontario, Can.
Jose J. Reynoso, . . . . .	Mexico City, Mex.
Herbert William Ross, . . . . .	Copperopolis, Cal.
Henry Claus Schmidt, . . . . .	Matuhuala, S. L. P., Mex.
George Brinton Upton, . . . . .	Wickenburg, Ariz.
William G. Whildin, . . . . .	Lansford, Pa.
Edwin F. Yates, . . . . .	Reno, Nev.

## ASSOCIATES.

E. P. Dudley, . . . . .	Britannia Beach, B. C., Can.
John Fred Thomas, . . . . .	Sharon, Pa.

## CHANGE OF STATUS.

Henry T. Bowles, . . . . .	New York, N. Y.
Walter Roberts Hodge, . . . . .	Mexico City, Mex.
Sheldon Smillie, . . . . .	Hancock, Mich.





## CHANGE OF ADDRESS OF MEMBERS.

The following changes of address of members have been received at the Secretary's office during the period of Sept. 1 to Nov. 1, 1907. This list, together with the list of changes of address published in *Bi-Monthly Bulletin*, No. 14, March, 1907, No. 15, May, 1907, No. 16, July, 1907, and No. 17, September, 1907, supplements the annual list of members corrected to Jan. 1, 1907, and brings it up to the date of Nov. 1, 1907. The names of members who have accepted election during September and October, 1907 (new members), are printed in *italics*.

The large number of changes of address since Jan. 1, 1907, shows the importance of publishing these changes as frequently as possible, and the *Bi-Monthly Bulletin* has been selected as the means to present this information to the members of the Institute. By the simple method of cutting out these names and addresses and pasting them directly over the corresponding names in the annual list of members, the record can be kept practically up to date, and the value of the list correspondingly increased. For this purpose the changes of address have been printed only on one side of the page. The names of new members, being in italics, are readily distinguished from the others, and can be pasted in approximate alphabetical order on the margins of the pages.

ADAMS, ARTHUR K., Prof. of Geol. and Mineralogy,	
	New Mexico School of Mines, Socorro, New Mexico.
AHBE, FREDERICK R.....	22 Thirteenth Ave., Newark, N. J.
*Alderman, Samuel J., Genl. Mgr., Indian Queen and	
	Blind Spring Hill Mines, Benton, Cal. '07.
*Armstrong, Lyndon K., Min. Engr. (P. O. Drawer 14), 615 Hyde Block,	
	Spokane, Wash. '07.
ARNOLD, C. E. LEN.....	Smuggler, Colo.
ASTLEY, JOHN W., Min. Engr., Care The British America Trust Co.,	
	Victoria, B. C., Canada.
AVERY, COLBY M.....	39 Cortlandt St., New York, N. Y.
BARBOUR, PERCY E.....	935 Middle St., Bath, Maine.
BLAKEMORE, GEORGE H.....	Great Cobar, Ltd., Cobar, N. S. W., Australia.
BOWLES, HENRY T.....	35 Wall St., New York, N. Y.
BRADLEY, OLIVER U.....	Hornitos, Mariposa Co., Cal.



- BRINEMADE, ROBERT B., Cons. Engr.....4429 Morgan St., St. Louis, Mo.  
*\*Brook, Reginald H. T.*, Mine Mgr., 119 Errard St.,  
 South Ballarat, Victoria, Australia. '07.
- BROOKS, ROBERT STEWART...Care Dr. L. D. Ricketts, Cananea, Sonora, Mexico.
- BROWN, AUSTIN H.....501 West St., Redding, Cal.
- \*Brown, Joseph, Mgr*.....Graphite Mines, Kelly, New Mexico. '07.
- BRUCE, JAMES L.....P. O. Box 83, Joplin, Mo.
- BUCK, ARTHUR H., Parker & Buck, Cons. Engrs., 309 Bartlett Bldg., Joplin, Mo.
- BUDROW, LESTER R.....Calle Roma 41, Mexico City, Mexico.
- CALLAGHAN, JOHN T., Jr.....508 North Seventh St., Chester, Pa.
- \*Campbell, Donald F.*, Min. Engr.....Heroult, Baird P. O., Cal. '06.
- CARR, PERCY E. O., Genl. Mgr., Mazapil Copper Co., Ltd., Apartado 64,  
 Saltillo, Mexico.
- CARSON, GEORGE C.....Vancouver, Wash.
- \*Church, John A., Jr.*, Min. Eng..... Apartado 25, Guanajuato, Mexico. '07.
- CLERC, F. L.....The Shirley Hotel, Denver, Colo.
- COSBY, FREDERICK N.....Corbin, Mont.
- COX, STERLING B.....P. O. Box 17, New York, N. Y.
- CREMER, FELIX.....Fundicion, Sonora, Mexico.
- GROOKE, ROBERT L.....101 Beekman St., New York, N. Y.
- DALY, HERBERT J., Care Bank N. S. W., 64 Old Broad Street,  
 London, E. C., England.
- DAVEY, GEORGE.....The Cabin, Weseliff-on-Sea, Southend-on-Sea, England.
- DAVIS, CHARLES HENRY.....South Yarmouth, Mass.
- DOUGLAS, THEODORE, Prest., Compania Metalurgico y Refinadora del  
 Pacifico, S. A., Fundicion, Sonora, Mexico.
- DOUGLASS, ROSE E.....Choix, Sinaloa, Mexico, via Nogales, Ariz.
- DOWNES, W. F.....75 Fairview Ave., Jersey City, N. J.
- DUFOROQ, EDWARD L., Room 435, Produce Exchange Bldg., New York, N. Y.
- EDMONDSON, HORACE W., Veta Colorado Min. & Smltg. Co.,  
 Villa Escobeda, Chihuahua, Mexico.
- EILERS, KARL.....320 Central Park W., New York, N. Y.
- EMLAU, HARLAN S.....Greenback Mining Co., Leadville, Colo.
- EWING, FREDERIC, Draftsman, Steptoe Valley Smltg. & Refg. Co., McGill, Nev.
- FARISH, GEORGE E., Care University Club, 2a Bucareli 809, Mexico City, Mexico.
- \*Fellows, Aubrey P.*, Asst. Supt.....Picher Lead Co., Joplin, Mo. '07.
- FERRY, CHARLES H.....Room 603, 114 Liberty St., New York, N. Y.
- FIELD, WILFRID B.....American Club, Mexico City, Mexico.
- FINCH, JOHN W., Secty.....Goldfield Cons. Mines Co., Goldfield, Nev.
- FOSTER, ERNEST LEN.....3430 Colfax Ave. B., Denver, Colo.
- FRANKE, EMIL A .....1742 Magnolia Ave., Chicago, Ill.
- GALVIN, CARROLL D.....1311 Franklin St., Oakland, Cal.
- GARRISON, F. LYNNWOOD.....760 Drexel Building, Philadelphia, Pa.
- GIBSON, C. H., Mgr., Trinidad Min. & Smltg. Co., Arcelia, Guerrero, Mexico.
- GIFFORD, STANLEY D., Secty. and Treas., United Copper Co.,  
 74 Broadway, New York, N. Y.
- GILCHRIST, PERCY C.....Reform Club, Pall Mall, S. W., London, England.
- GIPPS, F. G. DEV.....Irvinebank, North Queensland, Australia.
- GLEESON, WALTER G., Gold Reef Mining Co., Gilt Edge, via Lewistown, Mont.
- GOLDBERG, JULIUS.....Instructed to hold all mail.
- GOODRICH, R. R., Prof. of Met.....University of Arizona, Tucson, Ariz.
- GOUYARD, GUSTAVE M.....Room 1542, 42 Broadway, New York, N. Y.



- GRAHAM, KENNETH M., Trigonometrical Surveyor,  
Raub-Pahang, Federated Malay States, Straits Settlements.
- \*Groom, Thomas C., Min. Engr., Great Cobar, Ltd.,  
Cobar, New South Wales, Australia. '07.
- GUESS, GEORGE A., Met.....Tennessee Copper Co., Copperhill, Polk Co., Tenn.
- HAMMON, WENDELL P.....1204 Merchants Exchange Bldg., San Francisco, Cal.
- HANCKEL, CHRISTIAN, Care Zinc Corporation, Broken Hill,  
New South Wales, Australia.
- HARDINGE, HAL. W.....43 Exchange Place, New York, N. Y.
- HARDY, J. GORDON.....631 Prospect Ave., El Paso, Texas.
- HILL, ROWLAND F.....Pulaski Mining Co., Pulaski, Va.
- HILL, WALTER HOVEY, Cons. Engr.....Tenabo, Lander Co., Nev.
- †Hodge, Walter R., Min. Engr., Care Carpenter & Brennon,  
519 La Mutua, Mexico City, Mexico. '07.
- HOLT, HERBERT L.....Care Tom Boy Gold Mines Co., Ltd., Smuggler, Colo.
- HORSBURGH, JAMES, Chillagoe Co., Ltd., Chillagoe, North Queensland, Australia.
- HOWELL, JOHN .....First National Bank, Watonga, Okla.
- HYBINETTE, VICTOR.....Fredericktown, Mo.
- IRELAND, JAMES D.....Buhl, St. Louis Co., Minn.
- IRVING, JOHN D., Sheffield Scientific School, Yale University, New Haven, Conn.
- JAMISON, CLAUDE E., Min. Engr., De La Mars Gold Mountain Mines,  
Victorville, Cal.
- JARVIS, ROYAL P.....1700 Cornell Ave., Knoxville, Tenn.
- JONES, WILLIAM STRICKLER.....Care Banco de Sonora, Alamos, Sonora, Mexico.
- JUDGE, ARTHUR T.....Box 38, Krugersdorp, Transvaal, South Africa.
- KANE, DANIEL B.....Apartado 708, Lima, Peru, South America.
- KIMBALL, EDWIN B.....1204 Merchants Exchange Bldg., San Francisco, Cal.
- KIRKPATRICK, GUY H., United Empire Club,  
117 Piccadilly, London, W., England.
- \*Kissam, William A., Coal Mining, Genl. Mgr., Insular Coal Co.,  
Manila, Philippine Islands. '07.
- KLYNE, RALPH C.....La Jolla, San Diego Co., Cal.
- LAKES, ARTHUR.....200 McPhee Bldg., Denver, Colo.
- LANCASTER, THOMAS.....235 West End Ave., New York, N. Y.
- LANE, HENRY M., Editor of *Castings* and Sect'y of the Foundry Supply Asso.,  
1137 Schofield Bldg., Cleveland, Ohio.
- LEE, MARCELLUS P.....1025 W. 11th Ave., Corsicana, Texas.
- LEWIS, CLANCEY M.....817 Pacific Block, Seattle, Wash.
- LIGHT, HERBERT H.....Apartado 20, Hermosillo, Sonora, Mexico.
- LINCOLN, FRANCIS C., Prof. of Geology and Mineralogy,  
Montana State School of Mines, Butte, Mont.
- LINDBERG, JAFET.....Pioneer Mining Co., Nome, Alaska.
- LINDSAY, LIONEL.....2 Cavendish Square, London, W., England.
- LINVILLE, C. P., Asst. Prof. of Met., School of Mines and Met.,  
Pennsylvania State College, State College, Pa.
- LODGE, JOSEPH.....South Pittsburg, Tenn.
- LODGE, RICHARD W.....375 Eighth St., Edmonton, Alberta, Canada.
- LOOMIS, EDWARD E.....19th floor, 90 West St., New York, N. Y.
- LUDWIG, CARL P., Genl. Mgr. and Supt. of Mines, Alabama Consolidated  
Coal & Iron Co., 12th Ave. and 12th St., Birmingham, Ala.
- LUNDBERG, JOHN.....79 P Street, Salt Lake City, Utah.
- MCBRIDE, WILBERT G., Supt. Sierra Cobre Mines, Box 58, Cananea,  
Sonora, Mexico.



- McLAUGHLIN, HAROLD M., Supt. of Mines, Central Chile Copper Co., Ltd.,  
Panulcillo, Coquimbo, Chile, South America.
- MAGEGEORGE, ALEXANDER J.....Glendury Grove, Malvern, Victoria, Australia.
- MANNHEIM, ERNEST A., Care W. Friedlander,  
48 Market Lane, London, E. C., England.
- \*Manning, John F., Min. Engr....Korean Exploration Co., Chiksan, Korea. '07.
- MEIKLEHAM, T. M. R.....25 Broad St., New York, N. Y.
- MILLS, RONALD V. A.....Care F. C. Mills, 20 Union Square, New York, N. Y.
- MITCHELL-ROBERTS, J. F.....Care U. S. Metals Ref. Co., Grasselli, Ind.
- MONTIS, ENRIQUE DE, Tegucigalpa, via  
Puerto Cortez, Rep. of Honduras, Central America.
- \*Moore, Robert McL., Mech. Engr., Genl. Mgr. Cobbs Hole Central Copper  
Mining Co., via Kianadra, New South Wales, Australia. '07.
- MOSS, CLEVELAND O., Southern Arizona Smelting Co., Saseo, via Red Rock, Ariz.
- MURPHY, THOMAS D.....Apartado 30, El Oro, Mexico.
- NEUSTADTER, ARTHUR.....238 Virginia Ave., Jersey City, N. J.
- NICOLL, BENJAMIN.....59 Wall St., New York, N. Y.
- NIS, EDWARD A., Genl. Supt., New York & Honduras Rosario Mining Co.,  
San Juancito, Honduras, Central America.
- PARRISH, SAMUEL F.....406 Citizens National Bank Bldg., Los Angeles, Cal.
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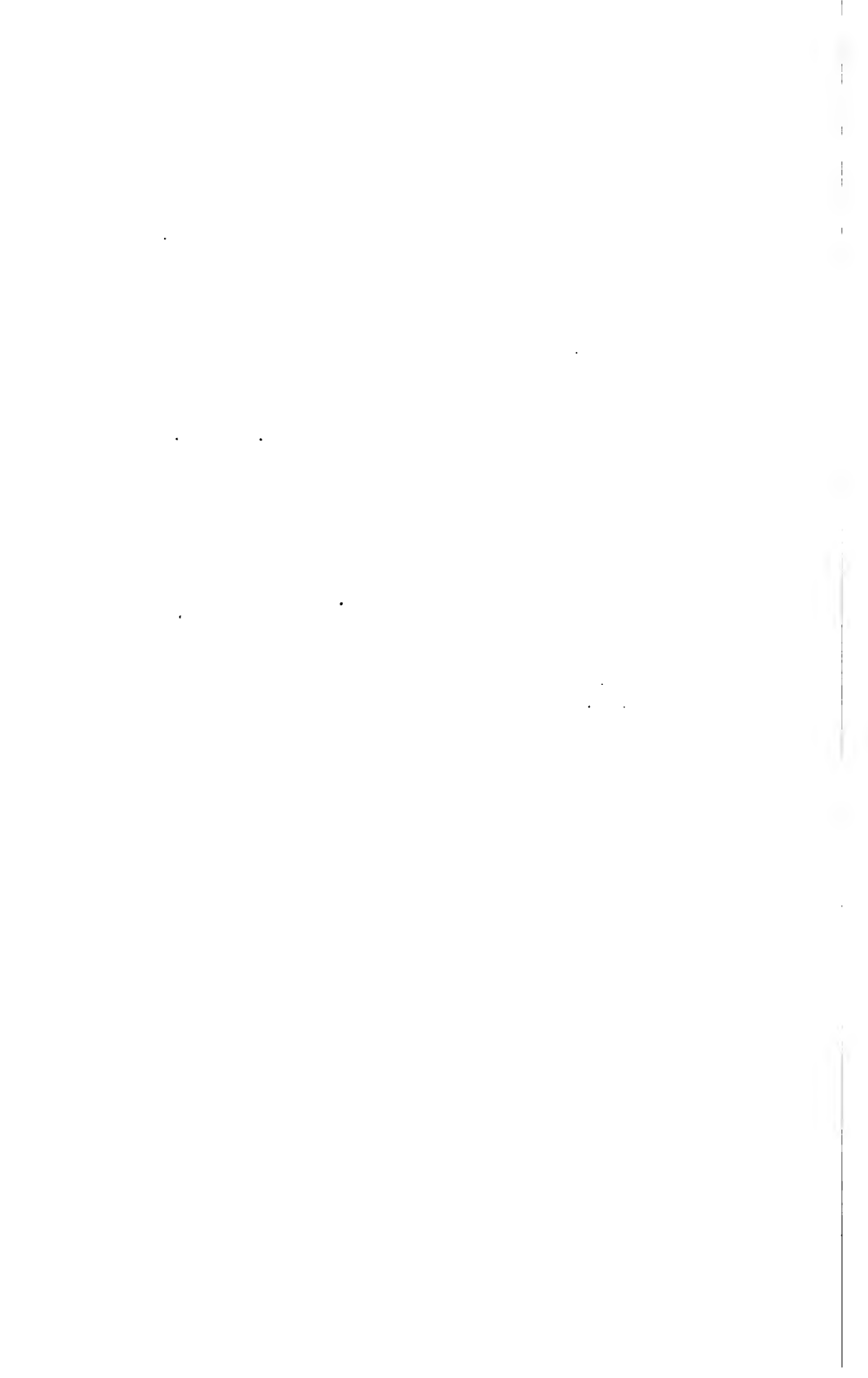


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# The Geological Relations of the Scandinavian Iron-Ores.

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(Toronto Meeting, July, 1907.)

CONTENTS.		PAGE
INTRODUCTION,		878
GROUP I. THE ORES OF THE ARCHÆAN CRYSTALLINE SCHISTS,		881
<i>Distribution,</i>		881
<i>The Rocks,</i>		881
Structures,		883
The Rocks of Norrbotten,		885
<i>The Ores,</i>		886
Type A. Apatite-Ores,		887
Type B. Mixed Hematite and Magnetite,		888
Type C. Quartz-Banded Ores,		888
Type D. The "Skarn"-Ores,		889
Type E. Limestone-Ores,		890
<i>The Origin of the Ore-Deposits,</i>		890
Arguments against the Sedimentation Theory,		891
Concentration and Transformation within the Deep-Seated (Anamorphic) Zone,		884
The Chemical Changes,		896
Transformations in the Surface-Zone,		900
<i>The Grängesberg and Norrbotten Deposits,</i>		902
<i>Analogous Deposits,</i>		905
GROUP II. THE ORES OF THE PORPHYRIES (KERATOPHYRES),		907
<i>Kiirunavaara, Luossavaara and Tuollavaara,</i>		908
The Syenite,		910
The Porphyry of the Foot-Wall,		910
The Porphyry of the Hanging-Wall,		910
The Ores,		911
The Forms and Dimensions of the Ore-Bodies,		913
Contact-Zones,		914
The Genesis of the Deposits		915
<i>Mertainen and Puinirova,</i>		917
<i>Ekströmsberg,</i>		919
<i>Analogous Deposits,</i>		919
GROUP III. MAGMATIC SEGREGATIONS IN BASIC ERUPTIVES,		920
<i>Taberg in Småland,</i>		922
<i>Segregations in Diabase Younger than the Dala Sandstone,</i>		925
<i>Iron-Ore in Nepheline-Syenite,</i>		926
<i>Ekersund and Soggendal in Norway,</i>		927

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	PAGE
<i>Routivare,</i> . . . . .	929
<i>Summary,</i> . . . . .	930
<i>Analogous Deposits,</i> . . . . .	933
<i>Utilization,</i> . . . . .	934
GROUP IV. THE IRON-ORES OF THE METAMORPHOSED CAMBRO-SILURIAN	
<i>SCHISTS,</i> . . . . .	935
<i>The Geological Horizon,</i> . . . . .	935
<i>Dunderland,</i> . . . . .	937
<i>Næverhaugen,</i> . . . . .	939
<i>Salangen,</i> . . . . .	939
<i>Other Deposits,</i> . . . . .	940
<i>Summary,</i> . . . . .	941
<i>Analogous Deposits,</i> . . . . .	943
GROUP V. CONTACT-DEPOSITS IN THE CHRISTIANIA REGION, . . . . .	
<i>Classification of the Rocks,</i> . . . . .	944
<i>The Ores,</i> . . . . .	944
<i>Analogous Deposits,</i> . . . . .	945
GROUP VI. LAKE- AND BOG-ORES, . . . . .	
	945

## INTRODUCTION.

From a geological point of view, the iron-ores of the Scandinavian peninsula may be classified as follows:

I. *The ores of the Archæan crystalline schists.* These ores belong to the division of the Archæan formation, crystallized in the anamorphic zone and interwoven with granites; the ores occur associated with ortho- and para-gneisses, granulites and dolomized or silicified limestones.

II. *The ores of the porphyries (keratophyres),* belonging to a division of the Archæan formation, plicated in pre-Cambrian time, but younger than the old granites.

III. *The ores of the basic eruptive rocks,* occurring as differentiations in intrusives of diabase, gabbro and norite, forming stocks, bosses or laccolites within schists of Archæan and Silurian age.

IV. *Ores occurring in the metamorphosed Cambro-Silurian schists,* chiefly in the mica-schist group, characterized by mighty beds of limestone.

V. *Contact-formations connected with acid eruptive rocks* of post-Silurian age, in the Archæan gneisses and in the Silurian limestones and argillaceous schists.

VI. *Lake- and bog-ores,* belonging to the most recent geological period.

This classification is neither genetic nor based on the age of

the ores. However, the above groups are well defined, and hardly any transitions between them can be found. There is generally no difficulty in deciding to which of the groups a certain ore-deposit is to be referred. In drawing up the present scheme a consideration of the rock or the geological unity with which the different ores are connected has furnished the chief ground of classification.

In this connection a review of the geological age of the different kinds of ore-bearing rocks—which is not always the same as the age of the ores—is of some interest.

The ores of Group I. occur in those older Archæan rocks which are interwoven with granite. With respect to their present characters, form, textures and mineral constitution, the ores of this group are younger, or, at least, no older, than the plication of the rocks.

As for the age of those rocks with which the ores of Group II. are connected, it seems not to be established with certainty, but it is evident that these rocks belong to a younger division of the Archæan. The ores frequently exhibit epigenetical characters with respect to the rocks.

The ores of Group III. are connected with rocks of highly varying age: Taberg in Småland forms a laccolite of olivine-diabase in the oldest Archæan formation; Routivare is an intrusion in the metamorphosed Cambro-Silurian schists of the Scandinavian mountain-ridge and is, consequently, younger than these, which is, probably, also the case with the ore-bearing gabbro of Lofoten and Vesteraalen. The nepheline-syenite in Alnö is post-Archæan. The ores belonging to this group are syngenetic formations.

The ores of Group VI. lie in rocks of Silurian age; but it was only in connection with, or after, the post-Silurian rock-plication that the ore-formation was finished.

The ores included in Group V. occur chiefly in the normally developed Silurian formations of the Christiania basin, as well as in Archæan gneisses, but they are genetically connected with post-Silurian eruptive rocks, and consequently of the same age as these.

The different geological ore-groups are characterized by mineralogical and chemical properties, which have been determinative of their technical utilization.



The lake- and bog-ores of Group VI. were, on account of their cheap exploitation and easy reducibility, the earliest raw-material of iron-manufacture in the Scandinavian countries; but their importance has been decreasing as the iron-manufacture has become a great industry. They occur chiefly in Sweden, but also in Norway.

The ores of Group I. were next utilized. Owing to the absence of phosphorus and to other excellent qualities characterizing some of these ores, they were for centuries the only ores that were mined in Sweden, and they have been the raw-material of the Swedish iron that has won world-wide renown. These ores occur especially in Sweden, but also in certain parts of Norway.

The ores of Group II. could not for a long time be utilized on account of their high percentage of phosphorus; moreover, the situation of the deposits in the extreme north of the Scandinavian peninsula discouraged mining enterprises. Some of the deposits of this group are among the greatest in the world. Thanks to the basic refining methods, they have now gained great importance, and are more and more utilized for the Swedish iron industry; having, however, as yet chiefly given rise to an ore-export on a large scale. The ores of this group occur only in Sweden.

The ores of Group III. are chemically characterized by a high amount of titanium, which makes them very difficult to reduce. They have hitherto been made use of on a very small scale only. Vast deposits of them occur in both Sweden and Norway.

The ores of Group IV. occur only in the metamorphosed Silurian formations of Norway. They are characterized by a comparatively low percentage of iron, and have not as yet been utilized for the Scandinavian iron-industry, but preparations are going on for mining and exporting them on a large scale after subjecting them to magnetic concentration.

The iron-ores of Group V. have a limited distribution within the Silurian and Archæan rocks of the Christiania basin. They are of no practical importance.

## GROUP I.—THE ORES OF THE ARCHÆAN CRYSTALLINE SCHISTS.

*Distribution.*

These ores are chiefly distributed within "the ore-province of central Sweden" (see Fig. 1). Outside of that area they occur in the province of Norrbotten (Gällivare, Svappavare, etc.), in northern Sweden, and in Varanger, in northern Norway. On the southern coast of Norway, in the neighborhood of Kragerö and Arendal, there is an isolated district carrying these ores.

*The Rocks.*

The ore-bearing rocks of the ore-province of central Sweden are chemically and petrographically unlike the more monotonous gneiss- and granite-areas which surround them. On the whole, they constitute a quartz-feldspar formation in which purer quartzitic rocks, limestones, "*skarn*"-rocks and ore-bodies are very subordinate members. (*Skarn* is the Swedish name for rocks of varying composition, mostly consisting of lime-, magnesia-, iron- and alumina-silicates of the pyroxene-, amphibole- and garnet-groups; as secondary minerals, epidote, chlorite, biotite and talc occur. The *skarn* is scarcely an independent rock but is connected with the ore-deposits. It is formed through an interchange between the silica of the quartz-feldspar rocks and the basic constituents of the ore-formation.) Among the feldspar-rocks there are certain types, which occur constantly in different areas—viz., the amphibolitic plagioclase-rocks and the granulitic rocks composed of quartz and alkaline feldspars. Among the latter soda-granulites as well as potash-granulites are met with; also the corresponding gneisses occur. Differentiations of pure quartz-muscovite-rocks and rocks richer in alumina constitute more subordinate types.

H. Johansson, in a highly remarkable contribution to the subject,<sup>1</sup> has recently pointed out some characteristics in the composition of the ore-bearing formation. He shows that within certain areas a complex of granulitic and amphibolitic rocks is met with under conditions recalling the products of a

<sup>1</sup> *Geol. Fören. Förhandl.*, Stockholm, vol. xxviii., pp. 516 to 538 (1906); vol. xxix., pp. 143 to 186 (1907). The end of this paper is not yet published.

magmatic differentiation. The amphibolites (generally called dioritic schists) correspond to decided femic rocks with a con-

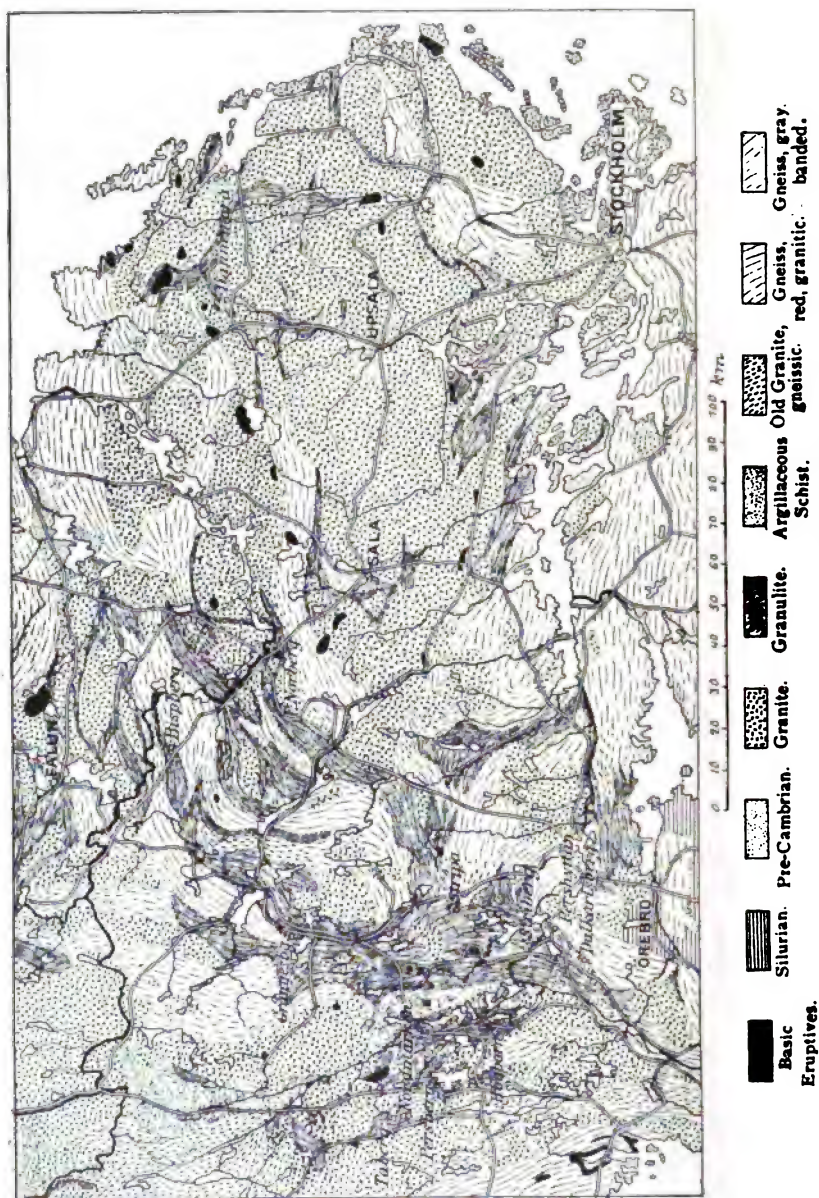


FIG. 1.—ORE-PROVINCE OF CENTRAL SWEDEN.

tent of  $\text{SiO}_2$ , not exceeding 53 per cent., while the granulites correspond to salic rock-types with at least 67 per cent. of  $\text{SiO}_2$ . The intermediate members are almost lacking.

The amphibolites have the composition of diorites and must be considered as stretched and dynamo-metamorphosed dioritic rocks. A part of the granulites correspond chemically to known types of granite. Thus it is highly probable that igneous rocks enter, to a great extent, into the composition of the ore-bearing granulite-formation.

Chemically the granulites may be divided into two groups: one containing the types with predominating plagioclase feldspar; the other showing plagioclase- and orthoclase-feldspars in equal quantity, or with the latter predominating. On the whole, the distribution of rocks rich in soda among the ore-bearing granulites seems to be considerable.

Among the ore-bearing gneisses and *hällfrinta*-rocks also, the rocks rich in soda are frequent. The potash-rich, red "*järnagneiss*," with a more granitic composition, and the "*garnet-gneisses*," rich in alumina, contain, on the contrary, very few ore-deposits.

The quartzitic rocks within the granulite-formation are nearly free from iron-ore-deposits, but often contain sulphide ores instead. The zones carrying these ores are often characterized through a series of quartzitic rocks containing anthophyllite, cordierite, light garnet, etc.

*Structures.*—According to their coarser or finer crystalline structure, the ore-bearing rocks are divided into gneisses, granulites and *hällfrintor*, the latter sometimes porphyritic. The ore-deposits prefer the fine-grained rock (granulites), but are also found in the coarse-grained gneisses as well as in the compact *hällfrintor*. As already pointed out, these rocks are very nearly related, chemically. Yet it is evident that the iron-ore-deposits are in some way connected with the rocks of granulitic structure; greater or smaller ore-deposits are found in nearly all the granulitic zones; and even the deposits in gneissic rocks lie not far from the boundary of the granulite. It is also noteworthy that the ores in the gneisses are generally not directly surrounded by true gneiss, but that the rock close to the ore-deposit assumes a more fine-grained, granulitic structure. This is observed at several ore-deposits in the gneisses of southern Dalarne (in the parishes of St. Tuna and Ludvika), as well as in Södermanland. A much more close-grained structure is also observed in certain granulites in the vicinity of the ore-bodies, where the rock may assume a compact *häll-*

*finta*-like structure—for instance, at the mines of Sköttgrufvan, Qviddberget in Dalarne and others.

It is most probable that the granulitic structure in general is due to a recrystallization under stress and movement, within the anamorphic zone of depth. The coarser gneissic and granitic rock-material has thus been granulated, and the size of the grain reduced. This has been the case not only over the broader granulitic areas but also along the granulitic zones in the gneissic areas, which thus in a certain way correspond to shearing-zones. Simultaneously with the mechanical deformation of the rock-masses there has been also a supply of iron-bearing magmatic material by solutions, imparting to the ore-deposits their present peculiar epigenetic characters.

To the processes undergone by the granulitic formation during submersion in the anamorphic zone belongs also the intrusion of the numerous pegmatitic dikes which at so many mines (*e.g.*, the mines of Pershyttan, Grängesberg, Ludvika-district, Gellivare) penetrate the ore-deposits as well as the surrounding rocks. These pegmatites are to be considered as secretions with a low temperature of crystallization, deposited from aqueo-igneous solutions in contraction-fissures due to the cooling of the surrounding rock.

A porphyritic structure, denoting effusive surface-rocks, is observed in several *hällfintor* (Dannemora, Utö). Other structures characteristic of surface-rocks, such as more or less evident stratification, may be seen in the rocks surrounding several ore-deposits (*e.g.*, Striberg and Utö). The stratification is locally shown as a striping in the contact between the limestone and the *hällfinta* at Dannemora. In other ore-deposits, especially those of the *skarn*-ore type, it is common that the rock close to the ore-body exhibits an irregular or twisted structure (as at Persberg), or is traversed by numerous fissures, or even becomes brecciated (as at Gellivare). This seems to indicate that the ores were deposited in shearing-zones, or perhaps that the chemical changes connected with the replacement of the rock-constituents by the ore-substance caused a considerable reduction of volume, followed by the disturbance of the rock referred to.

A secondary form, often observable in the granulite, is the linear structure caused by stretching of the rock. This often

shows, as at Lekomberga and Vintjern in Dalarne, a connection with the form of the ore-bodies, where the stretching is conformable to the pitch of the ore-bodies and to the linear structure of the surrounding rocks.

The true nature of the granulite-formation seems hardly to be fully explained, but it certainly contains rocks of different origin. That the amphibolites and a great part of the real granulites are igneous rocks of deep-seated origin, seems to be beyond doubt. But the residual structure of some of the *hällfintor* makes it probable that these are igneous surface-rocks. Other surface-rocks are the limestones and the quartzites. The very rare conglomerates belong to a younger division of the Archæan than the ore-bearing granulite formation. As in older times "graywacke" was a common name for a number of imperfectly known rocks, so it is to-day with the name granulite (or "*hällfintagneiss*" of the Swedish Geological Survey). Further investigations will certainly divide this group into rocks of very different nature and origin, only having in common certain structural features. The same is true as to *hällfintag*.

In the ore-bearing district of southern Norway (Arendal, Näs, Kragerö) which in most points agrees with central Sweden, the chief rocks are fine-grained gneisses, amphibolites and quartziferous rocks.

*The Rocks of the Ore-Province of Norrbotten.*—The geology of this wide district is somewhat complicated. Granitic rocks, together with syenite, syenitic porphyries and crystalline schists, here dominate in it; moreover, basic eruptives of the diorite and gabbro family are frequent. A series of clastic rocks (metamorphosed sandstone and conglomerate, together with limestone) of indeterminate age is exposed in several places.

The rocks of syenitic composition—*i. e.*, real syenite, syenitic porphyry and granite—are found in Norrbotten to a larger extent than in central Sweden. The same may also be the case with the basic eruptives of the gabbro and porphyrite families. The rocks of both regions consist, however, mainly of granites, gneiss-granites and granulites—*i. e.*, quartz-feldspar rocks.

The granites are not ore-bearing, and seem not to be even indirectly connected with the formation of the ore. The granu-

lite contains several large ore-deposits of the same type as those of central Sweden (Gellivare, Svappavare). The largest deposits are, however, genetically connected with the syenitic and porphyritic rocks (Kiirunavaara, Luossavaara, etc.), belonging to Group II. of the preceding classifications. The gabbro-rocks of the district have their special deposits (Routivare) belonging to Group III.

The rocks inclosing the iron-ores of Varanger in the north-eastern part of Norway are chiefly gabbros, amphibolites and quartz-feldspar rocks. According to G. Henriksen, who reported upon these ores, the rocks are of igneous origin, but strongly metamorphosed.

### *The Ores.*

The ores belonging to this group may be divided into five sub-groups or types. The classification given below derives its origin from the metallurgical experiences of former times, when the Swedish iron-ores were divided, according to their behavior in the blast-furnace, into three kinds: (1) ores smelting in the blast-furnace without any flux, corresponding to the type C, in which the gangue itself contains the components of an easily fusible flux; (2) the quartzose ores, corresponding to types A and B, which require the addition of flux-making bases; and (3) the ores rich in lime, corresponding to type D, generally used to make suitable charges by mixture with the quartzose ores. This division, founded on the practical utilization of the ores, was adopted in 1874 by Anton Sjögren, who pointed out that the old division of the blast-furnace men corresponds to distinct geological ore-types. The apatite-ores, having at this time no great utilization, were not included in the system. In 1893, I added the apatite-ores as a special type, in which I have been followed also by H. Johansson in his discussion of the genesis of the Swedish iron-ores. Later on I divided the quartz-bearing ores into two types, A and B.

*Type A.* Ores containing apatite (type of Grängesberg, Gellivare).

*Type B.* Mixed hematite and magnetite, rich in silica and alumina and with a scaly or flaky structure (type of Lomberget).

*Type C.* Banded quartziferous hematites, rich in silica, and with a striped structure (type of Striberg).

*Type D.* Magnetite ores associated with silicates of lime, magnesia and alumina (type of Persberg).

*Type E.* Magnetite and hematite-ores associated with limestone and dolomite (type of Dannemora and Långban).

Between the different types transitional members may be found; but these are quantitatively subordinate, and all the important deposits belong to some of the above-defined types.

From a chemical point of view, these types form a series from the most acid, containing up to 50 per cent.  $\text{SiO}_2$ , to the most basic, type E, with only a few per cent. of  $\text{SiO}_2$ .

Taking into consideration all the chemical and geological characters of the ores, H. Johansson has arranged the different ore-types in the following order: apatite-ores, quartz-ores rich in alumina, quartz-banded ores, *skarn*-ores, and ores with limestone.

*Type A. Apatite-Ore.*—Besides the apatite, which may be uniformly intermixed or distributed in stripes in the ore-mass, the gangue consists only of a few per cent. of silica and feldspar. These ores originally were magnetite, but in many places have been altered to specular hematite through a process which simultaneously reduced the percentage of apatite. The apatite-ores are richer in iron (of which they carry from 60 to 65 per cent.) than the other types. The ore-bodies are generally well defined against the country-rock, and are frequently bounded, at least on one side of the ore, by "*sköl*" formations consisting of biotite, amphibolite or chlorite. They belong especially to the part of the granulitic formation characterized by amphibolite and plagioclase-granulite. As in the type B also, dikes of pegmatite are frequently present to a considerable extent.

In the ore-province of central Sweden the apatite-ores are represented by a number of important deposits, containing more than half the available ore-quantity. They are confined to a comparatively narrow district in the southern part of Dalarne, containing the Grängesberg, Hammar, and Blötberg mines, and several others. In the ore-province of Norrbotten this type is represented by Gellivare.

In southern Norway this type also occurs, represented by the Nissedal deposit and by the Soldal and Lyngroth mines.

These ores are either products of magmatic differentiation in the granulite or of metasomatic replacement of the feldspar-



rock by iron-bearing solutions in the anamorphic zone. Considering that only the first-named way of formation would explain the constant large amount of apatite in the ore, I look upon that hypothesis as the more probable.

*Type B. Mixed Hematite and Magnetite.*—The ores of this type, as is indicated by their territorial distribution, are nearly related to the preceding. They also show transitions to the ore-deposits of the next following type; but the regular banding is not developed, although a certain parallel structure is frequently to be seen. The ores of this type are scaly or granular in structure, and consist generally of magnetite and specular hematite mixed. The gangue is chiefly quartz, together with some mica and feldspar—the same constituents as compose the wall-rock. The percentage of iron is generally from 50 to 55 per cent., and richer concentrations are not very common.

The ore-bodies exhibit generally no defined boundaries, but show transitions into the wall-rock; frequently (*e.g.*, in the Ludvika district) the ore is disseminated as a lean impregnation in the rock.

Characteristic are the numerous pegmatitic dikes, evidently segregations of the wall-rocks, crystallized in fissures of contraction in the anamorphic zone. They correspond to the segregations of quartz, so numerous in the ore-bodies of type C.

These ores are evidently formed through injection of iron-bearing solutions in the schistose rocks and partial replacement of the rock-forming minerals; the ore thus being much younger than the inclosing rock. They are found in their typical development only in two areas—viz., in the Nora district (the Pershytte and some other mines); and in the Grängesberg district (the Lomberg, Ormberg and Blötberg mines, and the greater part of the Ludvika mines).

*Type C. Quartz-Banded Ores.*—This type is characterized by the regular striping due to the alternation of ore and gangue, often even as clear as that of the banded jasper in the Lake Superior ores. The ore is chiefly specular hematite; the gangue mostly quartz (*e.g.*, Striberg, V. Bispsberg, Norberg in part). In several mines, however, lime-silicates in the form of garnet (Norberg, Gräsberg) or amphibole (Stripa, Utö)

enter into the gangue; the striping is then less regular. Epidote is found as a secondary constituent.

The deposits of this type often constitute regular bed-formed ore-bodies without any *skölar*, but generally sharply defined against the wall. The iron-percentage is generally 50 to 55; but richer secondary concentrations of magnetite are found in numerous mines.

The regular striped structure has generally been considered as a primary stratification, in accordance with the view applied to the banded jasper, with which this structure fully agrees; frequently the striping is plicated and contorted. If it thus corresponds to an original stratification, these ores must have been formed through the alteration of stratified rocks with maintenance of the structure. If, on the other hand, this peculiar structure is a secondary feature, produced during the replacement-process, which seems to be more probable, the ores have been formed by a more thorough replacement of the original rock. H. Johansson, who considers the ore of this type to be, like all the other ores of central Sweden, a product of magmatic differentiation, looks on the striping as produced through "a pure physico-chemical process."<sup>2</sup>

The most important deposits of this type are found in several districts—viz., Striberg, Strössa, Stripa in the governmental district of Örebro, Norberg in Vestmanland, Bispberg and Gräsberget in Dalarne, Utö in the governmental district of Stockholm, etc.

*Type D. The "Skarn"-Ores.*—These ores are regularly accompanied by a gangue-rock consisting of lime-, magnesia- and alumina-silicates, of the pyroxene-, amphibole- and garnet-groups, together with their products of alteration, epidote, chlorite, talc and serpentine. The gangue generally constitutes bed-like deposits, joining the different ore-bodies. The latter are generally more irregular in form than those of the preceding types, and are frequently bounded by *skölar*. They consist of magnetite containing about 55 to 60 per cent. of iron, and are especially frequent on the contacts between granulite and limestone or dolomite (Persberg, Nordmark), or between granulite and diorite (Högborn mines).

<sup>2</sup> *Geol. Fören. Förhandl.*, Stockholm, vol. xxix., p. 186 (1907).

The ores of this type have often been formed by metasomatic replacement of limestone and dolomite by iron-bearing solutions, the ore and the minerals composing the gangue thus being of younger formation than the rocks.

They occur mostly in the western part of the ore-province of central Sweden, at Persberg, Nordmark, Taberg in Vermland, Dalkarlsberg and Klacka Lerberg in the governmental district of Örebro; some of the Norberg mines in Vestmanland and the Nyång mines in Gestrikland belong also in this class, together with the ore-deposits of Arendal in southern Norway.

*Type E. Limestone-Ores.*—These ores are characterized by their occurrence in or together with limestone and dolomite; they frequently contain manganese. The gangue is composed of several silicates of manganese, such as knebelite, tephroite, rhodonite, and manganese-garnet. The ores are sometimes associated, as, for instance, at Långban, with manganese-ores (hausmannite, braunite).

The ore-bodies, being metasomatic deposits in limestone, are very irregular in form. They are frequently bounded by *skölar*. The source of the iron in the solutions which produced metasomatic replacement may have been either the limestone or some external rock.

These ores only occur in connection with limestone and dolomite. The most prominent representatives are Långban in Vermland, the Vikers mines, Svartvik, and the Stållberg mines in the governmental district of Örebro and Dannemora in Upland.

#### *The Origin of the Ore-Deposits.*

During the last century the ores of this group were regarded by Swedish geologists as sedimentary deposits, laid down together with the over- and underlying granulite formation. Such opinions were advocated by A. Erdmann, Anton Sjögren, A. E. Törnebohm, B. Santesson and others; among the Norwegian geologists Vogt has with eagerness developed this theory.<sup>3</sup>

<sup>3</sup> See, for instance, J. H. L. Vogt, *De lagformigt optraedende jernmalmforekomster*, *Geol. Fören. Förhandl.*, vol. xvi., p. 275 (1894); *Dunderlandsdalens jernmalmfelt*, *Norges Geol. Undersøgelse*, No. 15, pp. 56 to 63 (1894); *Om de lagrade jernmalmsfyn-digheternas bildningssätt*, *Werml. Bergsmannaför Ann.* (1896).

The same opinion has also been expressed by several foreign geologists, for instance, De Launay, *Annales des Mines*, Tenth Series, vol. iv., pp. 49 to 209 (1903), as well as in the German treatises on Ore-Deposits by Beck (1901), and Stelzner-Bergeat (1906).

Only with respect to the Gellivare ores, opinions were much divided, and several geologists—*e. g.*, Lundbohm, v. Post and Löfstrand—believed them to be of igneous origin.

Since 1890, the present writer has in several papers argued that metasomatic processes undoubtedly played a prominent part in the formation of these ores, and has been able to point out several analogies with the iron-ores of the Lake Superior region.

In this paper I shall attempt to show that the metasomatic processes must have taken place, not in the surface-zone but in the anamorphic zone, and that the ores bear fully, in their mineralogical features and association, characters of formations of the deep-seated zone.

In several cases, it may not be possible to determine whether the original iron-bearing material was the product of primary magmatic differentiation, as in the apatite-ores, or iron-bearing magmatic solutions producing metasomatic deposits, as in the lime- and *skarn*-ores, or possibly altered chemical sediments, as in the quartz-banded-ore type.

The iron-bearing solutions may frequently have been of magmatic origin, thus carrying iron-bearing material from below; or it may be that the very small amount of water contained in the rocks was sufficient, under the condition of dynamic metamorphism in the anamorphic zone, to collect and concentrate the iron particles. The occurrence of ore-deposits in connection with surface-rocks, above pointed out, and their absence in the greater granite laccolites seems to prove that the deposits are formed in a depth less than that in which the granite consolidated, but still in the anamorphic zone.

*Arguments Against the Sedimentation Theory.*—That these deposits are not sedimentary is indicated by the fact that the surrounding rocks are igneous. So long as the granulite of Grängesberg and Gellivare was considered a sedimentary rock, it was possible to ascribe the same nature to the ore-deposits. But this foundation of the sedimentary theory seems more and more to give way.

Again, the form of these ore-deposits differs as widely as possible from that of stratified bodies. They have been termed lenses, stocks, lineals, etc. In general, they are much more irregular than is consistent with a sedimentary formation.

Sometimes these ores divide or branch into the surrounding rock (see Fig. 2, showing the central part of Dannemora), a feature which does not agree with any known form of primary sedimentation, but must be interpreted as secondary. At other places, the ore incloses portions of the surrounding rock, which sometimes take the form of irregular sinuous bands, cutting obliquely through the ore from the hanging-wall to the foot-wall. (See Fig. 3, showing the central part of Grängesberg.) In such cases it appears that the overlying and the underlying rock, together with the narrow partition-walls

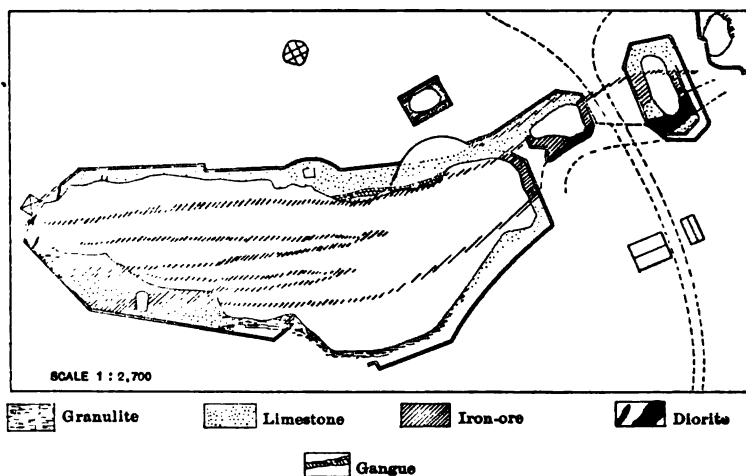


FIG. 2.—DANNEMORA MINE, CENTRAL PART.

between the ore-lenses, form “a continuous whole, pre-existing to the ore.” This mode of occurrence also is incompatible with sedimentary deposition.

In a few cases only, a structure resembling primitive stratification is met with; *e. g.*, in the banded quartziferous ores (type C), which for this reason possess special interest. The ores rich in silica and alumina (type B) sometimes present a schistose structure; but this is without any doubt a foliation caused by pressure.

Even where the stratified structure is present, we are not justified in concluding that the material is primitive; for in this case also, though retaining the original structure, it may have been subjected to subsequent metasomatic transformation.

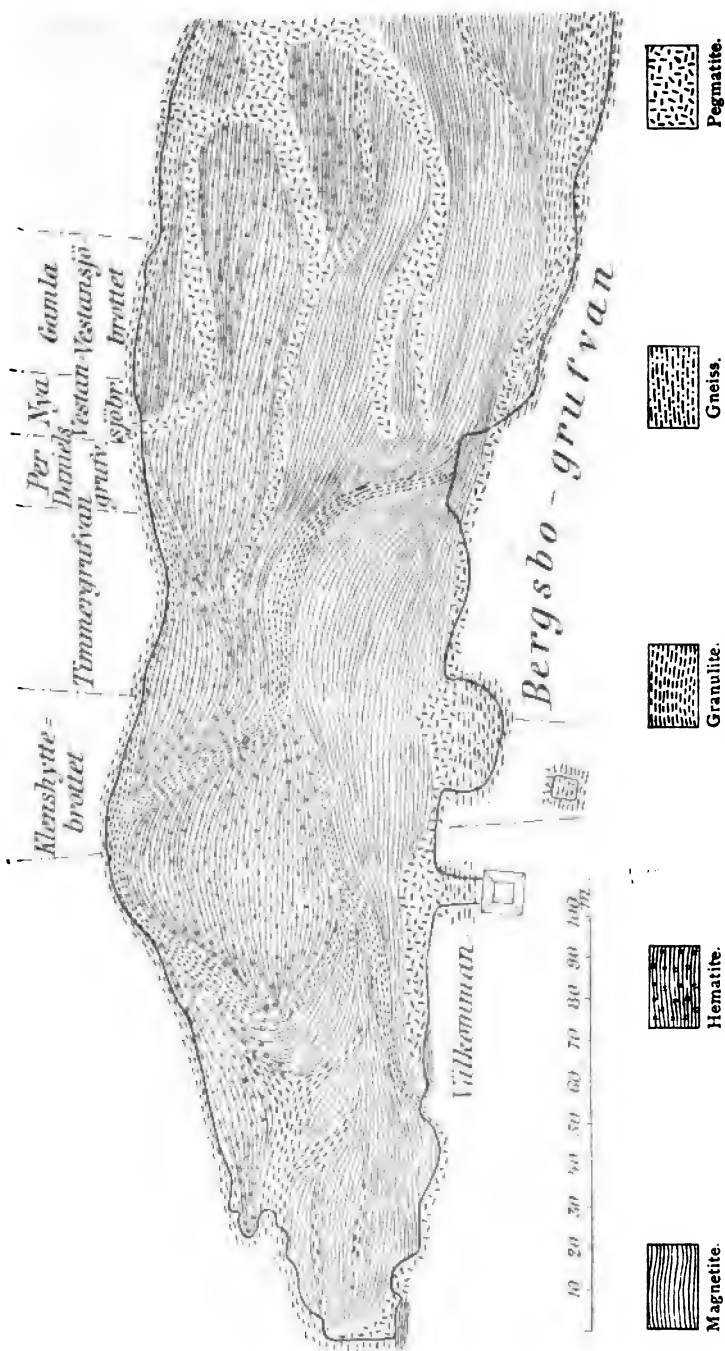


FIG. 3.—CENTRAL PART OF GRÄNGESBERG.

Thus the banded quartziferous ores may have originally consisted of alternating bands of a carbonate and of amorphous silica, since altered or replaced *in situ*.

*Concentration and Transformation Within the Deep-Seated Anamorphic Zone.*—To this zone the rocks were transferred during the period of the plication, by which evidently a part were folded to a considerable depth, being at the same time subjected to dynamo-metamorphic alterations, which in many cases determined their present characters.

During this period the ores and the gangue were formed by thermal iron-bearing solutions acting under high pressure. To what degree these solutions were magmatic, carrying ore-substance from below, or to what degree the small amount of water contained in the rock was active, it is not possible to determine. In either case, the process was different from the action of solutions circulating in open channels. It consisted in a solution of the rock-substance, which was intensified by the stress and friction, according to the principle of Riecke, and also in an accumulation and concentration of the ore, the surface-tension operating to unite particles of the same substance.

The ore-material, participating in the plication process, with its upheavals, folding and dislocations of the strata, has suffered some mechanical changes. One of the effects which, in many cases at least, may be ascribed to the mechanical folding is the peculiar overlapping which many ore-bodies present. This may be a primitive form of metasomatic deposition, but may also be considered as a result of the mechanical displacement of an ore-layer. Through a number of inclined or even vertical planes of dislocation, the deposit has been cut into pieces, which have then been somewhat displaced in relation to one another. Often these dislocations can be pointed out only with difficulty, or not at all; they are more obvious when the iron-ore occurs associated with a limestone-bed. (See Fig. 4, showing the plan of Ställberget.) The whole limestone horizon, with its accompanying iron-ore, is here fractured into several lenses, oblique to one another. The planes of dislocation have been effaced by the recrystallization of the granulite, and the schistose structure thereby developed, with its lamination running obliquely to the different lenses, which gives the

appearance of being situated on different levels of the stratigraphical series.

Another mechanical effect of the rock-plication is the stretching of the surrounding rock, by which it has assumed a linear structure, a system of smaller folds, with the axis of folding parallel to the stretching, having often been formed at the same time. In many cases (*e. g.*, the Lekoberga mine in the parish of Ludvika, and the Smedje and Mossaberg mines in Striberg), a connection between the stretching of the rocks and the pitch of the ore-bodies is observable, the axis of the stretching coinciding with the direction of the pitch. Yet it cannot be assumed as beyond dispute that this connection is in every case

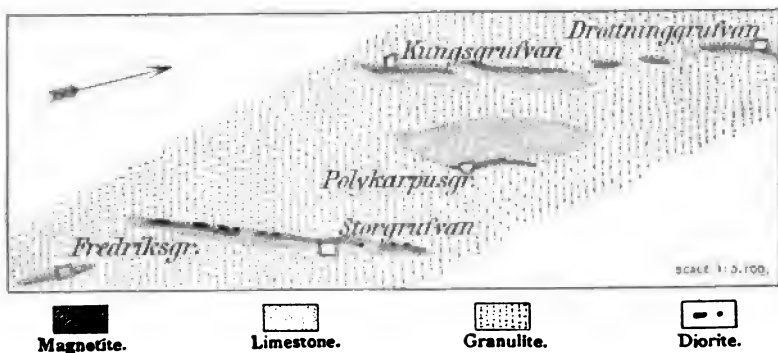


FIG. 4.—STÄLLBERG MINES.

due to a stretching of the ores themselves; it may also be explained as produced by the ferriferous solutions, chiefly following the directions indicated by the folds, formed simultaneously with the stretching of the rock.

The stretching of the rocks has given rise to the characteristic form presented by the Swedish ores of this type, which form is evidently due to a factor acting in a vertical direction. This form is represented in Fig. 5, which is a longitudinal section of part of the Svartvik mines, according to B. Santesson. Sometimes this form will be developed into such an extreme type as that of the mine of Stora Malmsjöberg, in which the ore mined in 1898 had, according to H. Sundholm, a length of 15 m., a breadth of 12 m., and a depth of 150 meters.



*The Chemical Changes.*—These have been much increased, not only by the high temperature in the anamorphic zone, but also by the stress and mechanical deformation, which tends to increase the solubility of the ore-material, as well as of the rocks.

The more easily soluble limestones were especially adapted to take up the ore-deposition; and generally great changes and transfers of the ores to secondary places of deposition have taken place in them, depending on water-courses, impermeable sub-strata, etc. The concentration has occurred especially along folds, fracture-zones, fissure-systems and contacts. Thus the ores assume the irregular, secondary forms characteristic of

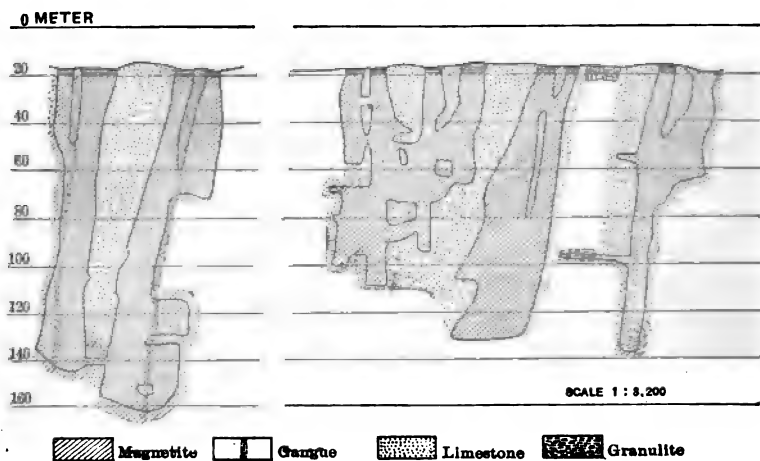


FIG. 5.—LONGITUDINAL SECTION OF THE SVARTVIK MINES.

metasomatic deposits, as shown in Fig. 2, representing the central part of Dannemora.

Other instances of concentration by solutions are offered by the fairly numerous cases in which the ore proves to be younger than dikes which traverse it. Such an instance is the Timansberg, a deposit of type D, which is traversed by minor dioritic dikes. Of these, C. H. Vrang writes that "in their vicinity the ore increases considerably in thickness."<sup>4</sup> In the Krangrufva, in the Persberg district, the rich and pure ore is chiefly found on one side of a large diorite dike; a dislocation is out of the question, for the ore-bearing layer is also found on the other side of the diorite, but without equally distinct ore-con-

<sup>4</sup> *Geol. Fören. Förhandl*, Stockholm, vol. ix., p. 244 (1887).

centration. H. V. Tiberġ has described how, in the Gustavus mine of the Långban district, a deposit consisting of specular iron-ore and magnetite, with gangue, continues from the surface to a flat system of diabase apophyses occurring at a depth of from 54 to 60 m., on which the ore spreads like a cake, while below the diabase-dikes the rock is dolomite only. In such cases the intrusive dikes have evidently preserved the underlying rock from transformation. A similar instance from Dannemora is mentioned by A. E. Fahlerantz,<sup>5</sup> who says that over a dike of *hällflinta* (felsite-porphry) a band of iron-ore a few inches in thickness was met with, accompanying the *hällflinta*. In this case, however, it is probable that the ore is a more recent formation; for the majority of the Dannemora ores are certainly older than the felsite-porphyrines.

Many limestone-beds have been largely, or even wholly, transformed into ores, especially of type D, the gangues of which, consisting of calcium- and magnesium-silicates, clearly indicate their origin.

At Utö it is questionable whether the concentration of the most prominent ore-deposit is not connected with the two traversing pegmatite dikes. The largest and deepest mines, which have followed the deposit down to a vertical depth of more than 200 m., are situated between these two pegmatite dikes; moreover, on the outer sides of the pegmatites there is a continuous ore-mass, which has been followed down to a comparatively great depth. At some distance from these dikes the ore has everywhere been less thick and less concentrated, and has, therefore, been mined on a small scale only. While the pegmatite dikes evidently originated at a great depth, it follows that the ore-concentration could not have been accomplished earlier than the submersion in the deep-seated zone.

The numerous mines of the Grängesberg, Blötberg, Fredmundsberg and Gräsberg districts offer good opportunities to observe the relation between the pegmatites and the ores. The former occur here as dikes, partly traversing the ores, and partly parallel to the stratification, but in a manner which indicates that they are of later formation than the ores. Coarsely crystalline magnetite is often found in the pegmatite veins, in-

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<sup>5</sup> *Vet. Ak. Handl. Bihang*, Stockholm, 4 (1876).

dicating that the aqueo-igneous solutions giving rise to the pegmatite originated from the same source as the iron-ore.

In this connection attention may be called to the not uncommon fact that the ores of this type occur along contacts, generally between limestone and granulite, but also along the contact

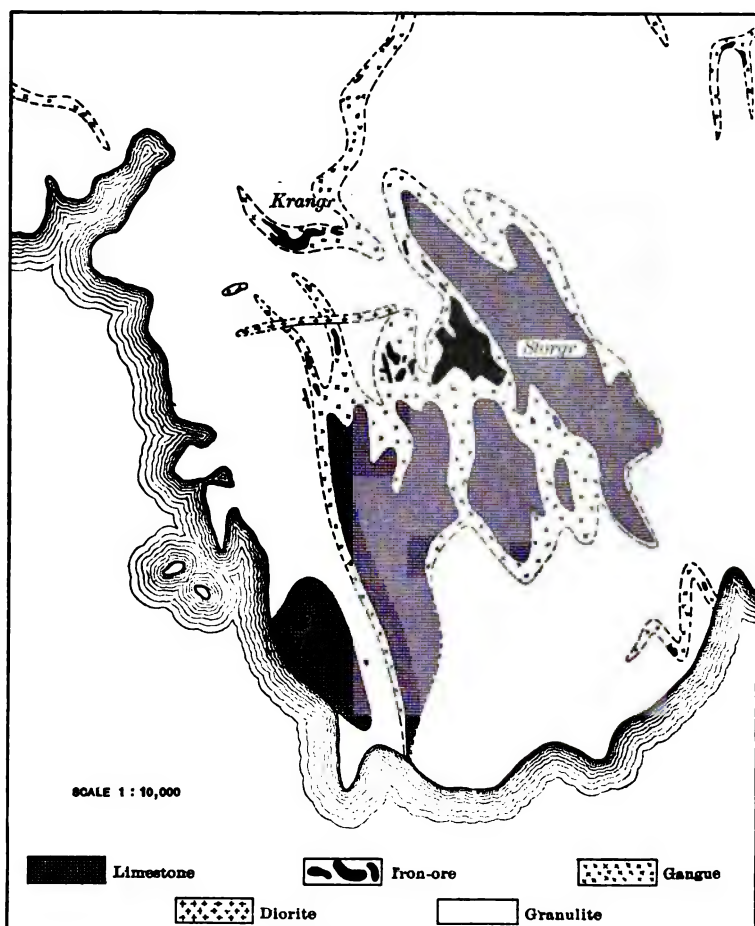


FIG. 6.—PERSBERG.

with intrusive rocks. A marked instance of the former mode of occurrence is seen at Persberg (Fig. 6), where the upper ore-bearing horizon occupies a basin with granulite in the foot-wall and dolomized limestone in the hanging-wall. Similar instances are found in several other ore-deposits of type D; *e. g.*, the Gasgrufve mine and the Nordmark mines in Vermland, and Sten-

ring and Ramhäll in Upland. In such cases the situation of the ores along the contact can hardly be explained by assuming them to be of primary origin; the only explanation possible is that the ores have been precipitated along the contact from ferri-ferous solutions.

The same explanation presents itself in such a case as that of the Högborn district in Örebro, where the most important deposits occur on a certain level between a diorite mass and the granulite (Fig. 7). If the ores were assumed to have been laid down as a sedimentary deposition on a certain level within the

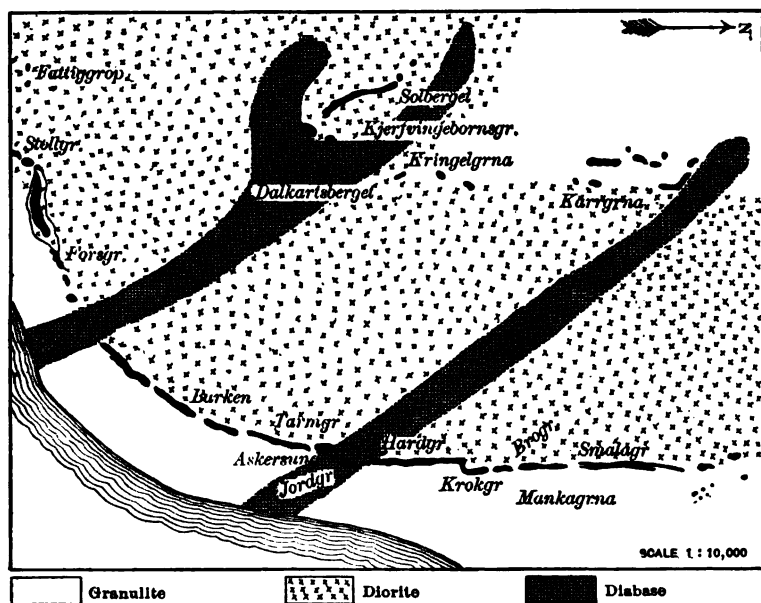


FIG. 7.—HÖGBORN MINES.

granulite, it would be necessary to explain the fact that the diorite had been injected on this very level and formed a laccolite there. The assumption that the ores are younger than the dioritic laccolite, and that they have been precipitated from ferri-ferous solutions, removes this difficulty. The most satisfactory view, therefore, is that the ores along such contacts are epigenetic formations.

To this period also belongs the formation of the gangues, which are the result of the silicification that takes place in the deep-seated zone. Whole layers of limestone have, through

the interchange of constituents, been transformed into lime-magnesia-iron-silicates (*skarn*-deposits). If the limestone has already undergone a dolomitizing process, or if Mg is added by the solution, the chief alteration-products will be amphiboles, which are rich in magnesia; if the limestones are comparatively pure, pyroxenes are formed. Though the garnet of the gangues may often be an alteration-product of pyroxene or amphibole minerals, it may, however, frequently be of primary formation, depending on the chemical composition of the solutions and the transformed material.

*Transformations in the Surface-Zone.*—When the erosion and removal of the overlying Cambro-Silurian strata exposed the Archæan rocks, the ore-deposits were subjected to the influence of catamorphic agencies.

Among the transformations of this period we have to note the formation of many *skölar* of chlorite and talc (soapstone) by the decomposition of the pyroxene and amphibole of the gangues or the granulite of the wall-rock. Many *skölar*, too, owe their origin to the decomposition of intrusive greenstone-veins.

Indeed, the whole mass of the gangues may, under certain circumstances, be changed, quite new ore-types being the result of the transformation. A common phase of this transformation is the occurrence of epidote, quartz and calcite in the gangue; if the alteration proceeds to a certain degree, hydrated minerals of the talc and chlorite groups are formed. As has been shown by H. V. Tibergh,<sup>6</sup> the gangue in the Taberg mines in Vermland, the ore of which is, in its upper part, markedly talcose, has been formed by metasomatic transformation of augite and amphibole. This transformation reaches only as far down as 320 m., at which depth the ore is cut nearly horizontally by a fissure which yields plenty of water. The same author adduces, also, the Alabama mine in the Persberg district as an instance of similar transformation; in its southern part the ore is talcose, but in the northern part the original gangues, pyroxene and amphibole, are still found. No doubt the ores of Dalkarlsberget, as well as all the ores belonging to the so-called "Rösberg type" of B. Santesson, ought to be in-

<sup>6</sup> *Wernl. Bergmannsför. Ann.* (1903).

terpreted in the same way, as being derived from type D through alteration.

Several other transformations may be viewed as comparatively recent and, consequently, belonging to this period. The ores of the Striberg type are often found to lose their characteristic bandedness in the direction of the strike, the quartz being replaced by a somewhat porous magnetite, sometimes also by calcite. Concentrations of richer magnetite often occur among the ores of this type; they are generally accompanied by quartzose segregations or chloritic *skölar*.

Simultaneously with this, a concentration of the iron may take place,  $\text{SiO}_2$  being dissolved by means of alkaline carbonates and the silica replaced by ferric oxides. It is by such concentration, for instance, the rich ore-deposits have been formed which are often met with in folds; *e. g.*, in Nordmark and in the Högborn mines in Vermland. In localities where very thick deposits of ore not enriched, and retaining the primitive structure, occur in folds, as at the Stripa mine, the abnormal thickness must be ascribed to mechanical deformation.

Among the Gräsberg mines, which are worked on a folded layer in the form of a trough sloping NNW., there occurs in the Bolag mine a highly concentrated magnetite in the fold, the rest of the ore being a poor hematite with quartz bands.<sup>7</sup> That a concentration process has taken place here is beyond doubt, though it is not possible to determine to what period it should be assigned.

On a still larger scale, a similar transformation has taken place in the Bispberg mine, producing a rich, pure magnetite, mined in the deeper levels of this mine, while in the upper parts the ore was a typical low-grade quartz-banded hematite.

Such transformation on a large scale of specular hematite into magnetite has long been known from several ore-deposits; *e. g.*, Norberg, Striberg, Gellivare. In the ends of the ore-bodies and in the sides contiguous to the surrounding rocks the transformation is most advanced, but also the interior portions of the ores consist of a mixture of specular hematite and magnetite. The cause of this transformation is not fully understood; but it is evidently a reaction, depending on mass-

<sup>7</sup> H. Sundholm, *Jern-Kontorets Ann.*, vol. liii., p. 162 (1898).

action, and continuing to a certain limit, where equilibrium ensues. It looks as if the reaction proceeded from the surrounding or traversing silicate-rocks; and it has been conjectured that the alteration has been produced by organic substances (humic acids) contained in the surface-waters descending along the walls of these rocks. Even though it might be supposed that these organic substances had the power of reducing specular hematite into magnetite, this explanation is not very satisfactory; for the transformation that has taken place is not a reduction of hematite into magnetite with retention of the structure of the former, but a solution and recrystallization of the iron-ore. One might rather suggest the action of alkaline solutions proceeding from the silicate-rocks, or some other reagent.

The change from hematite to magnetite is reversible; and in some places we meet with transformations on a large scale of magnetite into hematite. Of the anhydrous iron oxides, magnetite is more stable in the deep-seated zone, hematite in the surface-zone; and it seems safe to assume that the last-mentioned alteration belongs to the surface-zone. Such a transformation is found in the Grängesberg mines, where the ore close to the foot-wall consists of a scaly hematite low in phosphorus.

*The Grängesberg and Norrbotten Deposits.*

A separate position should be assigned to those ores of the type which are chiefly represented by the large deposits of Grängesberg, in central Sweden, and Gellivare, in Norrbotten. They diverge in some points from the majority of the ores of the Archæan schists; and their characteristic properties seem to be most satisfactorily explained by assuming them to be transformed basic segregations in gneiss-granites (orthogneisses).

In sketching the geology of Grängesberg I follow chiefly the notes given by H. Johansson.<sup>a</sup> In this district two ore-types are represented. The ores of the Lomberg-Risberg, and Ormberg mines, occurring in a real kali-feldspar-granulite, here represented by a reddish rock of uniform grain, have all the

<sup>a</sup> *Geol. Fören. Förhandl.*, Stockholm, vol. xxvi., pp. 361 to 363 (1904) and vol. xxix., pp. 174 to 176 (1907).

characters of the type B. To another type belong the vast ore-stocks of the Export mines, surrounded by a gray plagioclase-granulite, often, however, containing amphibole and inclosing numerous amphibolitic segregations. To the same class as the ores of the Export mines belong those of the Hammar mine, where the amphibolitic development of the rock is still more obvious, and several minor deposits; *e. g.*, the Långblåfall mines, which occur associated with basic rocks of dioritic type. It seems that these rocks are genetically connected with the gneiss-granite formation, developed immediately to the east of the Export mines. This formation varies in structure; in the central portions it is purely granitic and coarse-grained; nearer to where it borders on the granulite it becomes flaky, and the grain grows finer, only scattered porphyritic grains of feldspar remaining, till it passes into the fine-grained rock which incloses the ores; this rock becomes in places amphibolitic and dioritic (the mines of the Långblåfall mine.) On the whole, the ores, as well as the rock-complex inclosing them, present a peculiar lack of homogeneity in their composition, indicating segregations and concentrations in a magma. To the same class I refer also the Lekomberga deposits, likewise situated in a gneiss-granite (orthogneiss) formation.

The ore-deposits in the Export mines consist of composite stocks, the different parts of which are separated by partition-walls consisting of the same materials as the adjacent rock. (Compare Fig. 3.) The ores exhibit sharply-defined boundaries, and, in the composition of the gangues,  $\text{SiO}_2$  and  $\text{Al}_2\text{O}_3$  are subordinate to  $\text{CaO}$  and  $\text{P}_2\text{O}_5$  (belonging to the apatite); the percentage of P varying from 0.8 to 2 per cent. and being sometimes considerably higher. Generally, it is greater at the hanging-wall and smaller at the foot-wall. Titanite occurs abundantly in some of the ores.

In a still higher degree the gneiss-granite (orthogneissic) character of the rocks in Gellivare is manifested. This is pointed out in a convincing manner by Hj. Lundbohm, in his notes of the geological conditions of this deposit,<sup>9</sup> though

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<sup>9</sup> *Sveriges Geol. Undersökning*, Ser. C, No. 111 (1890), No. 127 (1892), and elsewhere.



he speaks with great caution on the question of the nature of these rocks. A true conception of this kind of crystalline schists was not at the time of his publications so well established as now.

The red gneiss dominant in the mountain of Gellivare is a rock with mostly allotriomorphic structure; where a parallel structure is found it is evidently a phenomenon of stretching. A porphyritic structure is found in several places. That the feldspar is plagioclastic indicates a rock rich in soda; the percentage of titanite is also remarkable.

Amphibolites, sometimes of dioritic type, occur in great numbers in the form of flattened lenses. Dikes of granite rich in soda occur, sometimes parallel with the stratification of the gneiss and with the strike of the ores, partly as masses, and differ from the gneiss chiefly or exclusively through their coarser structure. In some parts of the mountain rock-members resembling these granites rather than the gneiss inclose ores. The whole is a complex of rocks of common magmatic origin with a heterogeneity of composition depending on an advanced differentiation.

The Gellivare ores are in part surrounded by gangue-rocks, rich in ferromagnesian silicates, iron oxides, apatite, and sometimes titanite, which give evidence of the interchanges of material that have taken place between the ores and the surrounding rocks. These gangue-rocks are also in many places characterized by a brecciated structure.

The structure of the ore is coarsely crystalline, allotriomorphic. Among the structural peculiarities are the stretching phenomena, in the ores as well as in the rocks, which often give rise to a cleavage.

The latest secondary alterations concern the degree of oxidation of the iron. If the ores have been segregated from a magma, they have certainly been originally magnetites. However, Gellivare as well as the Export mines in Grängesberg consist to a large extent of specular hematite, which, consequently, is a secondary formation within the surface-zone. The formation of the specular iron-ore seems in places (especially in the foot-wall of the Bergsbo mine in Grängesberg) to have been attended with a far-advanced process of dephosphorization.

There are so many points of agreement between Gellivare and Grängesberg that it cannot be doubted that they have been formed in the same way. The heterogeneous nature of the surrounding rocks, the high percentage of apatite in the ores, often exceeding that of silicates, and the size and peculiar form of the ore-bodies, form the chief points of agreement.

The view expressed here concerning the nature of the ores of Gellivare and Grängesberg is in close accordance with the view advanced before by Löfstrand.<sup>10</sup> Similar opinions, especially concerning Gellivare, have been more or less positively advanced by several other authors in the lively discussion on the formation of these deposits which was carried on at the beginning of the nineties, in the last century, though at that date the problems concerning the Archæan rocks had not yet been proposed in a form that made a clear formulation of these views possible.

Also, the analogies between the deposits of Gellivare and those of Kiiruna have been repeatedly pointed out by Lund-bohm, Törnebohm, Holmquist, and others, with the remark that Gellivare is to be regarded as a transformed Kiiruna.

#### *Analogous Deposits.*

The ores of this group are well represented within the Archæan series of the United States and Canada; indeed, all the different types mentioned above are found there. This feature, that the same ore-types may be recognized in areas so far apart as North America and the Scandinavian peninsula, strongly indicates that these types correspond to certain genetical conditions. Of course, it may happen that other types, not represented in Scandinavia, may occur in the United States and in other areas. Only a few instances of the parallelism between the Scandinavian ores of this group and the Archæan ores of the United States and Canada may here be mentioned.

The ores of *Type A*—i. e., apatite-ores—are typically represented by the ores of the Mineville group, Lake Champlain district. I visited these mines in 1891 and was struck by the resemblance of the ore to the ores of Gellivare and Grängesberg.

<sup>10</sup> *Geol. Fören. Förhandl.*, Stockholm, vol. xvi., pp. 136, 137, 147, etc. (1894).

In hand-specimens the ore is hardly to be distinguished from the ore of the Swedish mines. Not only the mineralogical composition of the ore but also the form of the ore-bodies, the included "horses" of the wall-rock, the dikes of pegmatite and the amphibolitic segregations of the country-rock, offer strong analogies.

The ores of *Type B*, rich in silica and alumina, correspond in part to the Archæan ore-deposits of New York and New Jersey, as described in these *Transactions* by Frank L. Nason<sup>11</sup> and in several reports of the New Jersey Geological Survey. In the late description by Arthur C. Spencer,<sup>12</sup> who points out the connection of the New Jersey ores with the pegmatite-dikes, the agreement with the Swedish ores of this type is still plainer.

The quartz-banded, siliceous ores of *Type C* recall at many points the ores of the Lake Superior region, especially those of Archæan age on the Vermilion range. But also the ores of the older Huronian series of the Marquette and Crystal Falls districts agree in many points with the Swedish examples of this type. In comparing the Swedish and the American ore-deposits it must be noted that the unconcentrated ore with from 45 to 50 per cent. of iron corresponds to the banded jasper of the Lake Superior district, with a considerably lower percentage of iron, while the concentrations of magnetite in the Swedish mines correspond to the ores actually mined in the Lake district.<sup>13</sup>

*Type D*, the *skarn*-ores, have also their equivalents among the Archæan iron-ore deposits of New York, New Jersey and Pennsylvania. To the same type belong also the deposits of the Cranberry district, North Carolina-Tennessee, described by Arthur Keith.<sup>14</sup> The description so closely corresponds to the Swedish ores of this type, that it may be verbally applied to some of them. As already observed, I fully agree with Keith

<sup>11</sup> *Trans.*, xxiv., 505 to 521 (1894).

<sup>12</sup> *Mining Magazine*, vol. x., pp. 376 to 381 (1904).

<sup>13</sup> In 1891 I had the opportunity to visit the Marquette and Menominee districts; and after my return to Sweden, I pointed out in an address read Nov. 5 before the Geological Society of Stockholm, the analogies between the ore-deposits of Lake Superior and several of the Swedish iron-ores. The same was further stated in a paper on the same subject in 1893. *Geol. Fören. Förhandl.*, Stockholm, vol. xiii., p. 578 (1891), vol. xv., p. 473 (1893).

<sup>14</sup> *U. S. Geological Survey, Bulletin* No. 213, pp. 243 to 246 (1902).

concerning the origin of these ores as depositions through replacement by iron-bearing waters in the deep zone. Of the same type are also some of the deposits of eastern Ontario, in Canada. The agreement may be so close as to include mineralogical details also. In 1891, when visiting the Tilly Foster mine, Putnam county, N. Y., I was surprised by the mineralogical association in this mine, quite corresponding to Nordmarken in Wermland. The ore is in both places crystalline magnetite, intermixed with a gangue chiefly consisting of amphibole and pyroxene; magnesian silicates of primary and secondary formation are frequent. In both places occur as characteristic minerals fine crystallized magnetite, calcite, yellow titanite and transparent apatite; moreover, the alterations are the same. The minerals of the chondrodite group, so finely crystallized in the Tilly Foster, were at that time not known in the Nordmark mine, but were found there later, thus making the agreement still more complete.

Ores belonging to *Type E*—i. e., associated with limestones—seem to be comparatively scarce in the United States. Still, such ore-deposits are reported from Franklin Furnace, N. J., and from some other mines; they occur also in Ontario.

## GROUP II.—THE ORES OF THE PORPHYRIES (KERATOPHYRES).

The province of Norrbotten contains many times as much iron as all the rest of Sweden. Some of the deposits in this province may be reckoned among the largest in the world. The export from Kiirunavaara commenced as late as 1902, when the railway to Narvik on the fjord of Ofoten was opened; in the following year the exploitation of the less considerable neighboring deposit of Tuollavaara also began.

Geologically, the iron-ore deposits of Norrbotten are of three kinds: (1) the ores of the crystalline schists, which embrace the deposits of Gellivare and Svappavare, treated in the preceding section; (2) the ores of the Kiiruna type, connected with syenitic porphyries; and (3) ores connected with basic igneous rocks. These ores will be treated in the next section. (See Fig. 8.)

Topographically, the more important deposits may be divided into four groups: (1) Gellivare, embracing Malmberget and Koskulls Kulle and a few copper ore-deposits north of the Lina-

elf; (2) Svappavare, Leveäniemi and Mertainen, situated between the Kalix and the Torneå rivers; (3) a group in the vicinity of Lake Luossajärvi, embracing Kiirunavaara, Luossavaara and Tuollavaara; (4) Ekströmsberg, which belongs to the basin of the Kalix river. Besides these, minor deposits, for the most part only imperfectly known, are scattered all over the wide area.

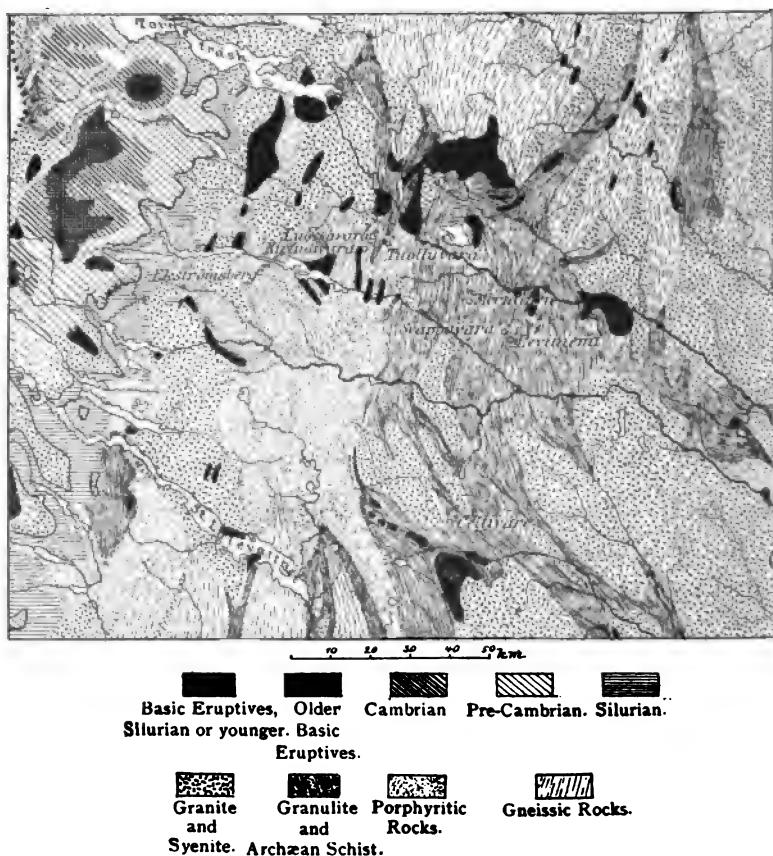


FIG. 8.—ORE-PROVINCE OF NORRBOTTEN.

*Kiirunavaara, Luossavaara and Tuollavaara.*

The iron-ore deposit of Kiirunavaara is undoubtedly the largest deposit of ore found in Europe. The neighboring deposits of Luossavaara and Tuollavaara are geologically of the same nature, though smaller. The first two of these deposits have been known for more than two centuries. Luossavaara is

mentioned as early as about the year 1690, Kiiruna not before 1786; a description of both is given in the Report of the Government Mining Inspector for 1751. The first survey was made shortly before 1760. Tuollavaara, being concealed under a thick moraine, was not discovered until 1897. (See Fig. 9.)

The ores in question prove to be genetically connected with a group of eruptive rocks of syenitic composition, and characterized by their high percentage of soda. These rocks show the structures of deep-seated as well as of vein-rocks. They are intruded in a sedimentary, partly clastic, complex of strata, including conglomerates and semi-crystalline schists.

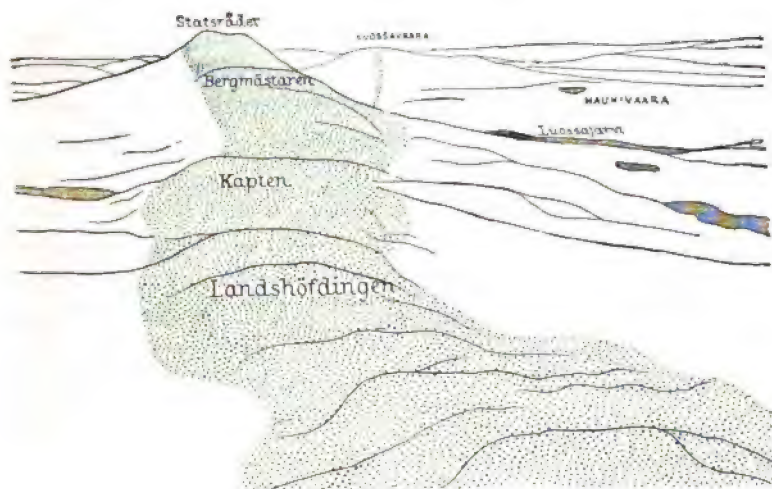


FIG. 9.—PART OF ORE-DEPOSIT OF KIIRUNAVAARA (LOOKING NORTH).

The porphyritic rocks were, for a long time, regarded by the Swedish geologists, Hummel, Gurnaelius, Fredholm, and others (in analogy with the case of central Sweden), as a sedimentary *hällflinta*, and the stratified rock-complex in which they occur was called *hällflinta*-schist. In 1889, however, Törnebohm pointed out the porphyritic nature of the so-called *hällflinta*, and afterwards the *hällflinta*-schists were found to consist of partly clastic rocks.

The ores of the three deposits form stratiform masses of considerably greater length than breadth—the length of the Kiirunavaara deposits is about 2.8 kilometers.

The ores are immediately surrounded by intrusive rocks of

porphyritic development which, on account of their composition, are to be referred to the soda-syenite-porphyrries. They have also been called keratophyres (H. Bäckström); however, as this name is applied to effusive rocks, and the effusive nature of the Kiiruna porphyries seems to me at least questionable, I prefer, for the present, the name porphyries. Two kinds of porphyry may be distinguished: one more basic, occurring chiefly in the foot-wall, but partly also in the hanging-wall of the ore, and one more acid, often developed as quartz-porphyry and occurring in the hanging-wall of the ores of Kiirunavaara and Luossavaara, around Tuollavaara, etc. The basic porphyry is closely connected with the syenitic rock which accompanies it.

*The Syenite.*—This is a soda-syenite, the chief mass of which is a soda-feldspar. Secondary basic minerals are present in abundance. The structure is eugranitic. This soda-syenite shows gradations into the porphyry of the foot-wall, with which it is closely allied in composition.

*The Porphyry of the Foot-Wall.*—This rock presents, microscopically as well as macroscopically, a fluidic structure with a trachytoidal arrangement of the feldspar of the ground-mass; sometimes, also, spherulitic structures are observable. The primary structures are, however, frequently difficult to distinguish, being in part totally obliterated by the alteration of the rock. The basic constituents are almost wholly altered into amphibole, epidote, and chlorite. Magnetite seems to occur in two generations: one primary, the other of later immigration. As fissure-minerals, indicating a secondary action of pneumatolytic nature, occur amphibole, titanite, apatite, and magnetite. In the contact-zone the fissures sometimes form cavities a decimeter in diameter, filled with the said mineral combination.

*The Porphyry of the Hanging-Wall.*—This is considerably more acid (containing 10 per cent. more of  $\text{SiO}_2$ ) than the syenite and the porphyry of the foot-wall, which circumstance places it among the quartz-porphyrries. Quartz occurs in the ground-mass partly as so-called "*quartz globulaire*," but in larger quantities where the ground-mass has undergone a recrystallization. Here, too, a secondary generation of magnetite can be observed. The primary basic mineral constituents are completely altered,

having produced amphibole, epidote, and chlorite. The rock shows, even macroscopically, a distinct fluidic structure.

Segregations of pure magnetite, mostly in rounded pieces, are worthy of notice; these segregations sometimes show a concentric structure and at times inclose grains of the feldspar of the porphyry. When the fragmentary character is more distinct, they are probably portions of segregations, solidified in depth at an earlier date, which have been partly rounded by resorption. These segregations have also been interpreted as fragments of the great ore-body; and from this it has been concluded that the porphyry of the hanging-wall should be younger than the mass of ore.

The unmistakable "consanguinity" between the soda-syenite and the porphyries is manifested by the high percentage of Na, which varies between 5.5 and 7.5 per cent.; apatite, titanite, and magnetite are, besides, minerals common to the syenite, the porphyries, and the ore-deposits.

*The Ores.*—(In the following exposition of the Kiirunavaara and Luossavaara ore-deposits, I follow chiefly the official report made by Hj. Lundbohm in 1898.) The iron-ore occurring among the porphyry-masses forms, on the whole, pure, nearly homogeneous ore-deposits; other minerals found in it are of comparatively subordinate significance.

A property characteristic of the ore of Kiiruna-, Luossa-, and Tuollavaara is its general extremely fine-grained texture, which proves that it has been subject, to a slight degree only, to the action of recrystallizing agents. By this structure, which is also found in a few other ores in Norrbotten, this ore-type is distinguished from the rest of the Scandinavian ores.

The only mineral that occurs in the ore with undoubtedly primary characters is apatite, the distribution of which is exceedingly irregular, so that the percentage of phosphorus in the ore varies greatly.

In Kiirunavaara, chiefly close to the foot-wall, but also here and there in the interior of the ore, occurs an ore-type with mostly grayish-black and dull, compact fracture (Lundbohm's type 5). When examined with the microscope it proves to be interlarded with apatite individuals idiomorphically developed; its phosphorus-percentage is from 3 to 6 per cent. This ore frequently presents a stratiform structure.



The ore-type which quantitatively predominates contains the apatite in nodules and irregular lenses (Lundbohm's type 4). Here, too, the apatite seems to be, at least in part, of primary origin, since it occurs partly as a minute impregnation of the ore, partly in irregular nests and veins, giving rise to a struc-

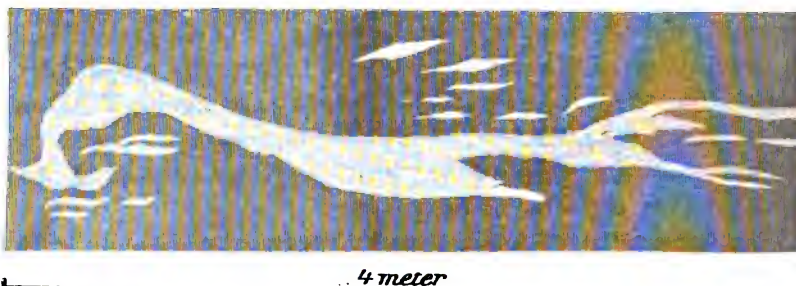


FIG. 10.—IRREGULAR VEINS OF APATITE IN MAGNETITE, KIIRUNAVAARA (Lundbohm).

ture which bears some resemblance to a largely developed flow-structure (Fig. 10).

Primary structural forms which may be referred to flow-structure may also be observed in the relation between different ore-types, when, *e. g.*, one type contains fragments or "*schlieren*" of another type, or when one ore-type occurs as intruding dikes

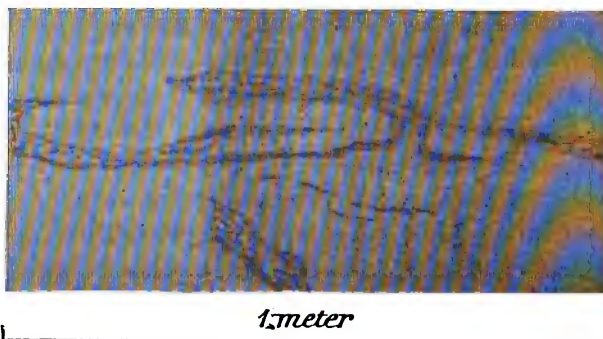


FIG. 11.—FLOW-STRUCTURE IN MAGNETITE, KIIRUNAVAARA (Lundbohm).

in another (Fig. 11). Especially on weathered ore-surfaces these structures are easily observable.

It is likely that the highly phosphoric ores, though embracing several types, must in general be regarded as primary, and those poorer in apatite as secondary, leached, and in part re-

crystallized. The latter also contain martite and specular hematite, the occurrence of which is here evidently secondary.

In the low-phosphorus ores occur also calcite (formed at the expense of the apatite), secondary quartz in fissures, and secondary silicates as amphibole, talc and chlorite minerals. The secondary ore-types are sometimes porous, the more soluble minerals having been leached out.

From a practical point of view, the ores in question have been divided into several classes according to their percentage of phosphorus. Those classes which range above 1 per cent. constitute the principal mass of the ores of Kiirunavaara. "As a fairly certain result of the examinations of the ores with regard to their percentage of phosphorus, it may be said that ores containing less than 0.05 per cent., and ores with from 0.05 to 0.1 per cent., of phosphorus, occur separately in such a mode that they can be utilized, but that both kinds, especially the former, are, as regards quantity, rather subordinate to those richer in phosphorus. The main mass of the ore of Kiirunavaara contains more than 0.8 per cent., generally from 1 to 2 per cent., not infrequently from 3 to 4 per cent. or still more, of phosphorus."<sup>15</sup> "On the whole the iron ores of Kiirunavaara may be said to contain a higher percentage of phosphorus than any other known ore-deposit of great extent."<sup>16</sup>

The phosphorus-percentages of the ores of Luossavaara, although exceedingly variable, seem mostly to be less than 0.1 per cent. In Tuollavaara, a part of the ores are also remarkably free from apatite, showing a phosphorus-percentage amounting to only hundredths of 1 per cent., but also here ores high in phosphorus occur.

Owing to the absence of other impurities, the iron-percentage of these ores is very high. That of Luossavaara fully equals or even exceeds that of the ore of Kiirunavaara. Apart from the ores richest in apatite, the average amount of iron is from 68 to 69 per cent.

*The Forms and Dimensions of the Ore-Bodies.*—The large ore-deposit of Kiirunavaara is an enormous mass, roughly rectilinear in outline. In length, the ore is exposed in the hills for more than 2,800 m., and through drilling and magnetical inves-

<sup>15</sup> Hj. Lundbohm, *Kiirunavaara och Luossavaara Jernmalmsfält i Norrbottens Län* (1898), p. 45.

<sup>16</sup> Lundbohm, *loc. cit.*, p. 55.

tigation has been proved to extend at least 1,200 m. further. In a northern direction below the level of Lake Luossajärvi, the deposit seems to divide in two narrow parallels, only known through magnetic investigation. The width of the deposits in some places exceeds 200 meters.

This enormous ore-body is cut in only two places by narrow masses of porphyry, extending from the hanging- to the foot-wall.

The boundaries of the ore against the rock are rather irregular, as may be seen in the outcrops, and the width of the deposit is thus very variable. Also the depth of the ore-body is remarkably irregular, which makes any calculation of the ore-quantity uncertain. The dip varies between  $45^{\circ}$  and  $60^{\circ}$  east. Generally, the dip of the foot-wall is a few degrees greater than that of the hanging-hall, indicating a downward decrease of width.

By diamond-drilling the dimensions of the ore-body have been in the main determined to a depth corresponding to the level of the Luossajärvi lake; beneath this level the ore is in some places proved to extend to a depth of 200 m., but concerning the dimensions of the body at this depth nothing is known.

The Luossavaara deposit exhibits the same features as Kiirunavaara, only on a smaller scale. It is known for a length of at least 1,200 m., of which 750 m. is exposed. This ore-body dips east about  $65^{\circ}$ . The decreasing width towards the depth is here still more evident than at Kiirunavaara.

*Contact-Zones.*—As to the relation of the iron-ore to the surrounding rocks, in many places a contact-zone, one meter or a few meters in breadth, is observable, in which occurs a mixture of ore and minerals belonging to the porphyry.

Thus in Kiirunavaara, within the porphyry of the foot-wall, ore-veins with indeterminate boundaries are found running through the rock. The branching veins form a net of wide meshes inclosing pieces of the rock. In one direction the ore-veins pass into fine fissures in the almost unaltered porphyry; in the other direction the magnetite prevails, and angular, strongly uralitized fragments of porphyry are found in the compact ore-mass. At last one finds only a dark-green amphibole in the magnetite as a reminder of the silicate-rock.

Inclosed masses of the surrounding rocks occur in many places in the ore, especially in the neighborhood of the foot-wall. Thus, in one place within an area of 40 m. in breadth streaks of, in part, considerably altered porphyry alternate with streaks of iron-ore; remains of porphyry altered into amphibolite and chlorite have also been found in the ore.

Also in Luossavaara similar contact-zones are found, though less accessible to the observer, on account of the thick covering of glacial deposits. Through the porphyry of the foot-wall, west of the top of the mountain, run veins up to 1.2 m. in width, containing magnetite, titanite and amphibole.

In Tuollavaara, also, a brecciated structure is found, perhaps better observable, though occurring on a smaller scale than in Kiirunavaara. The surrounding rock is irregularly cut by magnetite-veins and veinlets, giving rise to a breccia of sharp-edged porphyry-fragments, cemented together by magnetite; this phenomenon decreases as the distance from the ore-limit increases. Isolated breccia-like pieces of porphyry also occur inclosed in the iron-ore.

*The Genesis of the Deposits.*—The genetic connection of these ores with the porphyry-rocks is so manifest, that it has been admitted by all who have expressed their opinion on the subject. Even those geologists (Hummel and Gumælius in 1875, Fredholm in 1891), who regarded the porphyries as sedimentary *hällfintor*, acknowledged this connection, and consequently considered the ores as sedimentary formations. Löfstrand, in 1891 and 1892, in describing other basic segregations and vein-like formations of iron-ore in acid igneous rocks, pointed out that the connection of the ores of Kiiruna with the porphyries ought to be interpreted in the same way. The same opinion was expressed more positively in 1898 by Högbom,<sup>17</sup> who laid special stress on the agreement with the deposits connected with syenitic rocks in the eastern Ural: Wyssokaia Gora, Lebiajaia, and Gora Blagodat. A similar opinion was pronounced at a later time by O. Stutzer, who holds that the ores have been formed in an epigenetic-magmatic way as “eine nach oben gewanderte magmatische Ausscheidung”—i. e., a magmatic vein-formation.

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<sup>17</sup> *Geol. Fören. Förhandl.*, Stockholm, vol. xx., p. 115 (1898.)

A pneumatolytic sedimentary mode of formation has been maintained by Bäckström and, later, by De Launay (1903). The latter author, who gives the most detailed exposition of this view, has formed the following conception of the process: The porphyry of the foot-wall is an effusive rock, on which the iron-ore, formed through the decomposition of chloride and sulphide of iron in contact with water, has been deposited. Later on a new eruption of porphyry followed, by which the porphyry of the hanging-wall was formed.

This interpretation is based on the opinion that the ore is younger than the porphyry of the foot-wall and older than the porphyry of the hanging-wall, which, however, is hardly compatible with the fact that the magnetite is, in places, completely surrounded by the basic porphyry.

The above-mentioned fluidic structures in the magnetite can be accounted for only by assuming that the magnetite, together with the greater part of the apatite, has formed a segregation from an iron-alkali-silicate-magma, intruded as a vein between the porphyries. After this intrusion the effects of pneumatolytic agencies, which are especially well-marked at the contact with the basic porphyry, have arisen. Högbom has given a theoretical exposition of the formation of ores of this kind. He starts from an iron-alkali-silicate-magma composed, approximately, in the proportion of 1 molecule of orthoclase, 1 molecule of albite, and 1 molecule of magnetite. Such a magma differs in composition from known and common magma-types only by containing a little more ferric oxide and a somewhat smaller amount of lime and magnesia. As, at the solidification of such a magma, the larger part of the iron must segregate as magnetite, because, owing to the absence of lime and magnesia, it cannot combine with the silica, the differentiation of two rocks, one chiefly consisting of magnetite, the other of feldspar, is easily accounted for. Högbom, therefore, holds that the alkali-silicate-magmas rich in iron, to which petrography has as yet paid but little attention, have a just claim to a place in the system, and that their most typical representatives are magnetite-bearing syenitic rocks of this kind.

*Mertainen and Painirova.*

An interesting illustrative complement of what is known about Kiiruna is afforded by the statements, scanty and incomplete though they are, which are accessible concerning Mertainen, an ore-deposit of comparatively little importance, situated about 30 km. SE. of Kiiruna, within the group of deposits including also Svappavare and Leveäniemi, from which, however, it is quite different as regards geological conditions. These ores, too, are connected with a syenite-porphyry, mainly consisting of a soda-feldspar. At the contact with the deposit this rock has undergone a more or less advanced transformation of pneumatolytic character. The original basic rock-constituents have altogether disappeared, and new formations of magnesia-silicates appear in their place. The soda-feldspar has, in part, been transformed into scapolite, but also biotite and titanite have been produced.

In the syenite-porphyry, magnetite occurs, partly finely disseminated, partly as small segregations from the size of an almond to that of an egg. These have also been interpreted as cavity-fillings. The deposit proper, however, consists of a magnetite breccia (Fig. 12); a fine-grained magnetite fills the corrosion-fissures of the rock, sometimes associated with amphibole, less often with apatite.

Several of the ore-bodies have been found to extend to no great depth. The ore is a very rich magnetite, with a low percentage (generally less than 0.5) of phosphorus.

A deposit of quite the same character, Painirova, occurs 8 km. south of Mertainen. Here, too, one meets with a porphyry breccia with magnetite-veins and irregular ore-nodules; some of the veins contain apatite in abundance. The deposit seems to be of theoretical interest only. The syenite-porphyry presents partly a remarkable stratiform structure, and the gradation from the massive porphyry into this structure may be followed step by step.

The deposits of Mertainen and Painirova are evidently, like those of Kiiruna, genetically connected with the syenite-porphyries. But while at Kiiruna the magmatic characters of the ore-mass are most marked and the pneumatolytic characters subordinate, at Mertainen the reverse is the case. Breccia-for-

mations due to corrosion occur in both places, but form at Mertainen the larger portion of the deposit. The pneumatolytic phenomena which, at Mertainen, are manifested by a far-advanced scapolitization of the feldspar of the porphyritic rock

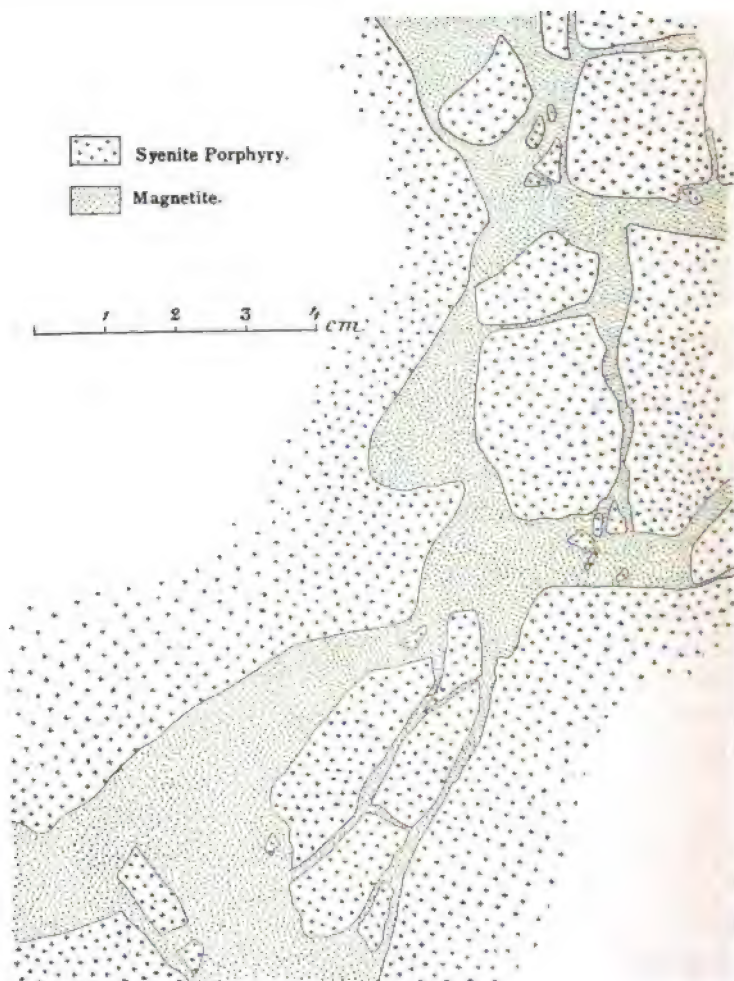


FIG. 12.—BRECCIATED IRON-ORE FROM MERTAINEN (W. Petersson).

and by the formation of biotite and titanite, are at Kiiruna of minor importance. On the other hand, Mertainen presents nothing analogous to the pure ore-masses of magmatic origin, and partly of fluidic structure, which form the main deposit at Kiiruna.

*Ekströmsberg.*

Ekströmsberg is situated about 80 km. west of Kiirunavaara. Here, too, the ore-deposit is connected with porphyry-rocks of syenitic composition; in the neighborhood, however, occur granites as well as greenstones, probably belonging to the same eruptive series. Part of the rocks show strong traces of dynamic action. The rock on both sides of the deposit is a quartz-porphyry of about the same acidity as the quartz-keratophyre of Kiiruna, yet differing from it by being a marked potash-rock. The deposit consists of a complex of magnetite and specular hematite, cut longitudinally by intrusive porphyries and porphyrites.

Though differing, by the potash of the surrounding porphyry-rock, from Kiiruna and its soda-syenite-porphyries, the deposit of Ekströmsberg belongs, in other respects, to the same well-defined geological group.

Besides the aforesaid deposits, a great many other iron-ores are known in Norrbotten. These ores are either associated with syenitic rocks, having then frequently a brecciated structure, or occur in the crystalline schists, sometimes as impregnations of magnetite, of great extent but little concentrated. Owing to the thick covering of moraine, these deposits have, as yet, been but partly and imperfectly examined; several of them are known only through their effect on the magnetic needle. Most of them seem to be of little practical importance.

*Analogous Deposits.*

The ores in Norrbotten of the Kiiruna type belong to a particularly well-defined geological-petrographical type, which is also met with in other parts of the world.

Högbom has already, in the above-mentioned paper, pointed out the agreement between the iron-ore deposits in the eastern Ural and the Kiiruna type. In the iron-mountains of the Ural a secondary epidotization of the rocks has taken place on a larger scale than in Norrbotten, especially along certain planes of dislocation. On the other hand, the pneumatolytic characters so well marked in the Kiiruna type are not met with in the deposits of the Ural. The secondary transformations, such as the development of martite and specular hematite, the leaching



out of pyrite and apatite, the formation of porous ore or ore containing calcite, and the accumulation of the apatite chiefly near the foot-wall, are common to the two districts.

The ores of the (for the most part exhausted) deposits of Iron Mountain and Pilot Knob in Missouri, which also occur in association with porphyry-rocks, have been compared to and classed with the Kiiruna type by several authors. At Iron Mountain the ore mined occurred as veins and irregular masses of martite and specular iron-ore in a mostly decomposed porphyry of Archæan age. At Shepherd Mountain similar deposits in porphyry were worked. The deposits of Pilot Knob, on the contrary, are secondary redepositions of the primary iron of the porphyry; they seem to bear a strong resemblance to the deposit of specular iron-ore in the Hauki schists east of Luossavaara.

Also, the Mexican deposits at Durango and Las Truchas agree in some respects with those in Norrbotten; but their geological conditions have not, as yet, been sufficiently investigated to make a direct comparison possible.

### GROUP III.—IRON-ORES FORMED BY MAGMATIC SEGREGATION IN BASIC ERUPTIVES.

The ores of this kind form a natural and well-defined class encountered in all parts of the world. That they are genetically connected with eruptive rocks has long been admitted. The nature of their facies of differentiation was not understood until the differentiation of rock-magmas was clearly conceived. In this regard, their structural characters, which are the same as those of the eruptive rocks, and their frequent presentation of all degrees of transition to the normal rock are evidential. (Fig. 13.)

Magmatic differentiations of this kind seem to be connected only with intrusive eruptives, and occur in laccolites as well as in vein-like intrusions. In general, a distinction can be made between such differentiations as have taken place within the mass of the laccolite, *in situ*, and such as have taken place in the deep-seated magma. In the latter case the product of magmatic segregation has been carried up to the level of the laccolite by a separate act of eruption.

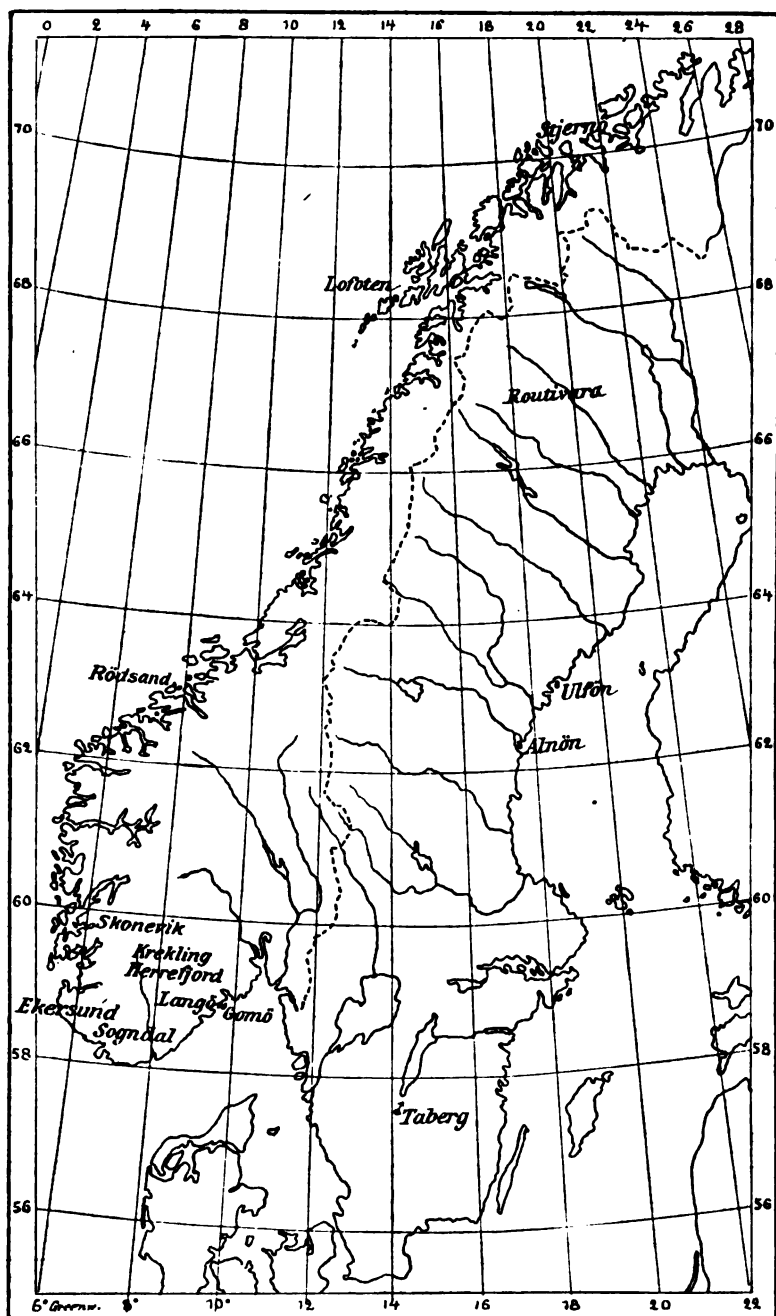


FIG. 13.—DISTRIBUTION OF TITANIFEROUS IRON-ORES.

*Taberg in Småland.*

As far as a hundred years back Hausmann<sup>18</sup> expressed the opinion that "the mass of Taberg is a greenstone bed of tolerably great thickness, mixed with much iron-ore and lying in gneiss." Through the investigations of A. Sjögren<sup>19</sup> and Törnebohm<sup>20</sup> it was established that the ore-deposit of Taberg ought to be considered as a segregation in a basic eruptive, the chief constituents of which are olivine, plagioclase, a rhombic pyroxene and magnetite. The structure is that of a deep-seated rock, and the rock, which has been called hyperite by the Swedish geologists, is olivine-norite according to the nomenclature of Rosenbusch. Taberg was the first iron-ore deposit interpreted as a phase of an eruptive rock. Törnebohm<sup>21</sup> says that the Taberg ore "may be regarded as a variety of hyperite rich in iron." As the ideas of magmatic differentiation were not clearly formulated until later, the nature of the ore could not in 1881 be expressed in plainer terms. The whole of the eruptive constitutes an intrusion (laccolite) in the surrounding gneiss, above which it now rises, by reason of its greater power of resistance to erosion. (Fig. 14.)

The ore-deposit occupies the central portion of the mountain. The ore-segregation consists of titaniferous magnetite and olivine and has received the petrographical name magnetite-olivinite. Where it approaches the normal rock, it first takes up plagioclase, then pyroxene, so that there is a transition from the ore to the normal rock, which also contains magnetite and olivine. The ore-stock thus forming the kernel of the mountain, is next surrounded by a shell or mantle of normal gabbro, which, in its turn, towards the inclosing gneiss, passes into the schistose, dynamo-metamorphic border-facies, the gabbro-amphibolite.

The ore is poor throughout, carrying generally from 20 to 30 per cent. of iron. Vein-like segregations containing up to 60 per cent. occur as rare exceptions. Titanic acid varies between 4 and 6 per cent.; the percentage of phosphorus does not exceed 0.1; to which may be added a constant percentage of vanadine.

<sup>18</sup> *Reise durch Skandinavien*, 1806-07, Part I, pp. 158 to 167.

<sup>19</sup> *Geol. Fören. Förh.*, vol. iii., p. 42 (1876).

<sup>20</sup> *Geol. Fören. Förh.*, vol. v., p. 610 (1881).

<sup>21</sup> *Loc. cit.*

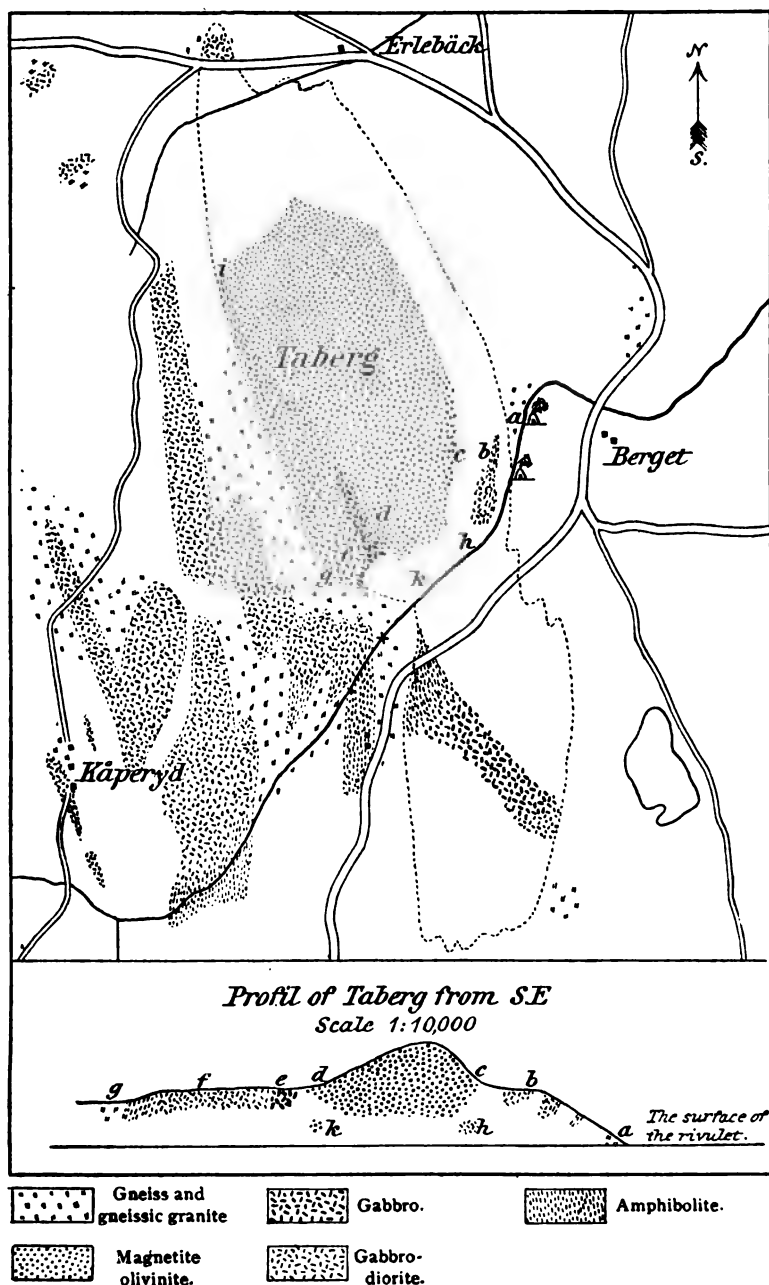


FIG. 14.—TABERG (Törnebohm).

Vanadine was discovered in 1830 by Sefström in ingot- and bar-iron produced from Taberg ore.

The ore of Taberg has been mined since time immemorial; during the 17th and 18th centuries it was the raw-material of a local iron-manufacture. As late as the fifties of last century twelve, and in 1875 ten, small furnaces were in operation, which used, chiefly at least, this ore. Since 1890, mining has been confined to the work required by law to escape forfeiting the licenses.

Other minor deposits of the same kind as Taberg occur in several places of central and southern Sweden. At Inglamåla in Jönköping a similar deposit has been worked, the ore being mixed for use with Taberg and lake ores.

Of essentially the same kind as these Swedish deposits are also several deposits in Norway. According to Vogt's description of the gabbro-masses in Langö and Gomö near Kragerö, these deposits agree very nearly with that of Taberg. They occur in an "olivine-hyperite," and the gradual concentrations can be followed from a gabbro rich in iron to a darker facies, poorer in plagioclase but richer in magnetite, at last passing into a rock containing no feldspar, consisting of magnetite and ilmenite together with iron-magnesia-silicates. The quantity of this ore is considerable, and at times it has been mined; it contains about 40 per cent. of iron with from 7 to 10 per cent. of titanitic acid. Similar to these is a minor deposit at Herrefjord near Porsgrund; of a somewhat different character is the deposit at Krekling, 6 km. E. of Kongsberg. The latter is distinguished by an uncommonly strong concentration of apatite in connection with the iron-segregation. The ore, consisting of concentrations of titano-magnetite, iron-magnesia-silicate and apatite (sometimes amounting to 25 per cent.), occurs in a gabbro containing hypersthene.

To this group we may probably also refer the numerous smaller deposits of more or less titaniferous ores which occur in many places in the older Archæan formation, in Sweden as well as in Norway, in diorites, amphibolites and amphibolite-schists, which rocks are to be interpreted as dynamo-metamorphosed eruptives. Such dynamo-metamorphosed basic eruptives with iron-ores are known from Rödsand, Tingvoldsfjord in Romsdal, where the deposit is said to lie in red and

gray gneiss; the iron-ore is titano-magnetite containing 8.20 per cent. of  $\text{TiO}$ , and 52 per cent. of  $\text{Fe}$ , mixed with amphibole and a little garnet. Of similar character is a deposit at Stalkjärn near Egeland, in Nedenäs.

*Segregations in Diabase Younger than the Dala-Sandstone.*

In the small islands scattered along the coast of Angermanland occurs a diabase in large masses overlying the Algonkian quartzite formation. The diabase forms bed-like intrusions between the stratified quartzites, and has been laid bare by erosion. It is an olivine-diabase of the type to which Törne-

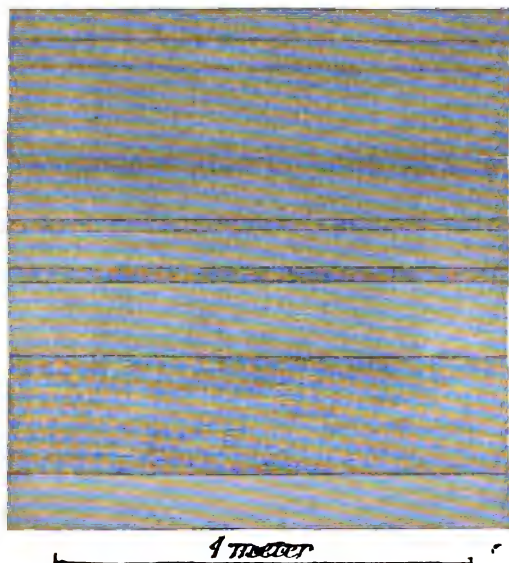


FIG. 15.—BANDED IRON-ORE FROM ULFÖ (H. Lundbohm).

bohm has given the name Asby diabase. The structure of this rock is ophitic; frequently a remarkable alternation of light and dark bands (leucocratic and melanocratic beds) is observable; in the melanocratic bands a concentration of titano-magnetite has sometimes taken place to a degree that gives them the character of iron-ore. This is the case in the islands of Ulfö, where a horizontal bed from 0.3 to 0.5 m. in thickness and of fairly large extent has been worked. (Fig. 15.) Overlying and underlying this bed there are several thinner ore-bands presenting a regularity like that of stratified rocks. It is evident that the distribution into bands which the magnetite

shows is due to the movement during the injection of the magma, and that the differentiation has taken place in the deep-seated magma basin. (The deposits in Ulfö bear great resemblance to the banded gabbro in the isle of Skye, described by Harker, and that of Deneschkin-Kamen in the northern Ural, described by Loewinson-Lessing.)

The percentage of titanitic acid may amount to 25 per cent. In the island of Trysunda the segregations occur in more irregular masses (Fig. 16). These ores are known since the middle of the 18th century, and have at times been utilized on a small scale—the quantity mined seems never to have exceeded 1,000 tons in the year—for the small blast-furnaces in the neighbor-



1 meter

FIG. 16.—SEGREGATIONS OF IRON-ORE, ISLAND OF TRYSUNDA (Lundbohm.)

hood, in which they have been mixed with other ores. Since 1876 no work has taken place.

#### *Iron-Ore in Nepheline-Syenite.*

In the island of Alnö, off Sundvall, occurs a boss of nepheline-syenite investigated and described by Högbom. Dike-formed rock-facies of the same eruptive series run through the Aaby diabase; the syenite-rocks, consequently, are also younger than the sandstone which underlies the diabase. The rock presents within the mass, of only about 4 km. in extent, a great many varying differentiated facies, with transitions from one to another. Also, limestones occur, which have been interpreted as segregations of an ultra-basic magma. In places the titanomagnetite has concentrated to poor ores, mostly, however, only

impregnations. Like the rock itself, these concentrations are of highly varying composition; some of them show a large amount of apatite with a P-content of 7 per cent.; others are free from phosphorus. The concentration of titano-magnetite has been accompanied with a concentration of olivine; on the other hand, feldspar is absent from the basic differentiations, which is also frequently the case with titanite, nepheline and cancrinite. For the rest, the ore is mostly accompanied by pyroxenes. The percentage of titanitic acid also varies from 9 to 12 per cent. These ore-deposits were worked in several small mines during the middle and latter part of the 18th century. Abandoned towards the end of that century, the mines were again worked in the beginning of the eighties of last century, but were abandoned again in 1884. On account of their high percentage of titanium, the frequently high amount of phosphorus and the low iron-percentage, a profitable exploitation of these ores is not very likely.

*Ekersund and Soggendal in Norway.*

In these localities the ore-deposits occur in a district of igneous rocks extending over 1,450 sq. km., and forming a section of a colossal laccolite consisting of a series of highly differentiated basic rocks of eugranitic structure. The age of the intrusion is considered to be post-Silurian. The most important differentiation-facies are: a feldspar rock consisting chiefly of labradorite, which occupies about two-thirds of the area; norites; and augite-granites; the first-mentioned rock being the oldest. Dikes of pegmatitic norite occur, besides dikes of norite of normal grain and of olivine-diabase. In the labradorite-rock as well as in the norite occur differentiation-facies rich in ilmenite, partly as ilmenite-norite, partly as veins of pure ilmenite. (Fig. 17.)

The deposits are distributed in two areas, the southernmost of which is the Soggendal field, where the main deposit is Storgången, a dike of ilmenite-norite, which, with sharply-defined boundaries, traverses the labradorite-rock; its length is over 4.6 km., the width varies between 20 and 70 m., it contains from 40 to 80 per cent. of titanitic iron, corresponding to from 20 to 40 per cent. Fe. The rock is often banded along the borders of the dike in alternating melanocratic and leuco-



cratic *schlieren*, indicating a differentiation in the deep-seated magma. It sometimes contains sharp-edged fragments of the wall-rock. In Blåfjeld, irregular segregations up to 50 m. in extent, of nearly pure titanitic iron, are met with. (Fig. 18.) According to Kolderup these deposits are in part real intrusive dikes, younger than the surrounding labradorite-rock, in part *schlieren*, lenses and dike-shaped masses formed by magmatic

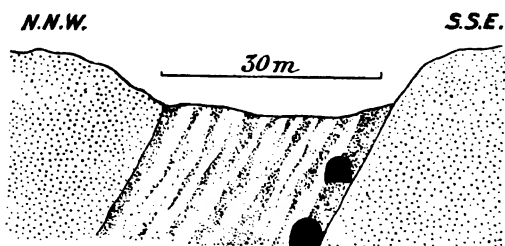


FIG. 17.—PROFILE OF STORGÅNGEN, SOGGENDAL (Vogt).

concentration *in situ*. The former (type Storgången) owe their origin to a differentiation of the deep-seated magma, the latter (type Blåfjeld) to a laccolitic differentiation. Kolderup describes ten such deposits, some of which occur as segregations, some as dikes. They are met with in the labradorite-rock as well as in the norite; the ilmenite dikes are consequently younger than these two rocks.

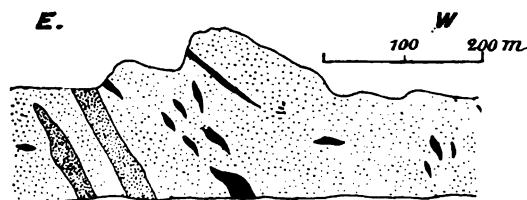


FIG. 18.—BLÅFJELD, SOGGENDAL (Vogt).

In the Ekersund field, dikes of titanitic iron of very irregular character occur distributed along a large dike of olivine-diabase. The ore-deposits, from 50 to 400 m. in length and up to 40 m. in breadth (only two of them, however, reach the latter dimension), frequently contain pure titanitic iron. As these deposits show sharply-defined boundary-lines at the contact with the inclosing rock, and also contain fragments of it, it can hardly be doubted that they are true dikes.

The ores of this district have been worked at different periods. Every attempt at a profitable exploitation has, however, proved a failure, owing to the high percentage of titanitic acid and the low percentage of iron. On an average, they may be said to contain 40 per cent. Fe. and from 40 to 42 per cent. of titanitic acid.

In the Soggendal field a good deal of mining work was performed from 1864 to 1876, especially in Storgangen and Blåfjeld. Also in the Ekersund field a considerable quantity of ore was mined from 1870 to 1875, and the total export from the two fields from 1864 to 1876 amounted to about 90,000 tons of ore, with an average percentage of 40 per cent. of iron and 40 per cent. of titanitic acid. These ores were mined by the Norwegian Titanitic Iron Co., and were smelted at the works of the company at Norton, near Stockton-on-Tees, England. In 1899 and 1900 a few thousand tons were extracted from the Soggendal mines.

Deposits of the same type as Ekersund and Soggendal are known in a great many places along the coast of Norway. The abrasion by the Atlantic and the deep indentation of the fjords running far inland have laid bare a large number of similar laccolites. Kolderup describes such deposits in the labradorite-rock field of the peninsula of Bergen, where minor deposits occur in groups at several places. At Bogstö in Skonevik, the peninsula of Folgefonden, such segregations occur in gabbro. The age of the rock and its geological correspondence to the aforesaid eruptive series is, however, uncertain.

#### *Routivare.*

One of the largest deposits of this class in Scandinavia is Routivare in Norrbotten. This deposit, which has been known for a long time, was formed by segregations in an intrusive rock occurring as a laccolite in the metamorphic Silurian formations. The strongly dynamo-metamorphosed character of the rock may possibly be explained as depending on its occurrence in the overlap-zone running along the eastern slope of the Scandinavian mountain-range. The ore-area has been estimated at 300,000 sq. m. at the surface. The eruptive rock consists of a gabbro altered almost past recognition and strongly saussuritized. The primary basic minerals have

totally disappeared; sometimes secondary aggregations of amphibole, serpentine, and garnet occur. The plagioclase is mostly recrystallized. The structure generally shows a lamination due to crystallization. The chemical composition agrees, in the main mass of the rock, with that of a labradorite rock. Besides this rock there occur in places, partly accompanying the ore, segregations rich in Mg and a composition corresponding to that of an olivine rock. The iron-ore, which occurs in highly irregular segregations, traversing the rock irregularly and with sharply-defined bounding surfaces, consists chiefly of titaniferous magnetite, but also contains ilmenite; other minerals met with are spinel, olivine, and pyroxene. This ore carries, in round numbers, 50 per cent. of iron, and 10 per cent., or more, of titanitic acid.

The deposit at Vallatj, a few kilometers north of Routivare, is of similar character, but of smaller extent, with an ore-area only one-eighth or one-tenth of that of Routivare.

#### *Summary.*

Though the rocks which inclose the deposits of this class differ in composition (as real gabbros, norites, diabases or nepheline-syenites), as well as in age (some of them belonging to the oldest Archæan formation, and the youngest dating from post-Silurian time), yet a marked degree of basicity seems to be a necessary condition for the formation of such concentrations. Vogt puts the highest acidity at 57 per cent.  $\text{SiO}_2$ . The majority of the deposits occur in rocks with a silica-percentage of from 48 to 54 per cent. The different facies of gabbro-rocks inclose deposits of different character. The pure ilmenite-segregations (Ekersund, Soggendal, Lofoten, etc.), seem to be confined to the labradoritic rock. In the same rock-series we also find the ilmenite-norite. In the olivine-gabbro, rich in magnesia, which incloses the deposit of Taberg, the segregation has assumed the mineralogical character of magnetite-olivinite, and in the rocks which are richer in alumina, magnetite-spinellite has been segregated, as at Routivare, Andopen, on Stjernö in Finnmarken, and elsewhere.

A remarkable feature of the ore-concentrations in question is their occurrence, almost without exception, in the central parts of the eruptive masses. This gives them a character dif-

ferent from that of those concentrations of basic constituents in an eruptive rock which are often met with along the margins of rock-veins, and in which the enrichment has not proceeded so far as to form an iron-ore.

As to the degree of concentration of the iron, the ore-types differ also from one another. The concentrates richest in iron are the magnetite-spinellites, with an iron-percentage exceeding 50 per cent. (Routivare, 50 to 54; Solnör, 54; Hellevig, 51; Andopen, nearly 60). Next to these come the segregations of the nepheline-syenites, of which in Alnö some contain from 46 to 53 per cent.; and after these the ilmenite-segregations in the labradoritic rock and the norite, with about 40 per cent. of iron, and nearly as high a percentage of titanic acid. Poorer still are the ores of the olivine-gabbros of the Taberg type, which contain little more than 30 per cent. of iron. Comparable to them are the ores of the olivine-diabase (the Ulfö type), with about 34 per cent. At the bottom of the scale stands the ilmenite-norite, the Storgång type, with about 21 per cent. of iron.

Besides the iron, it is chiefly the titanic acid, the magnesia, and the alumina that have been concentrated. The percentage of titanic acid is highest in the ilmenite-segregations of the labradorite and norite, where it amounts to from 39 to 43 per cent.; next come the ilmenite-norites, which contain 18 per cent.; the magnetite-spinellites (type Routivare) vary between 10 and 18 per cent.; the segregations of the nepheline-syenite show about 10 per cent. (the Trygg mine, in Alnö, from 9.10 to 12.14); in the Taberg type, the magnetite-olivinite, the percentage of titanium, like that of iron, is the lowest—viz., 6.30 in the Taberg ore and 8.50 in the ore of Långhult. The Ulfö type, with about 10 per cent.  $\text{TiO}_2$ , shows the greatest agreement with the Taberg type.

The concentration of magnesia has taken place not so much in the ore as in the concentration-facies between the normal rock and the segregations richest in iron. It manifests itself in the formation of Mg-Fe-silicates of the olivine- and pyroxene-groups. The rock-facies, which have received the names magnetite-olivinite, ilmenite-norite, and ilmenite-enstatite, have originated in this way. A certain percentage of Mg is found even in the purest segregations of ilmenite in the labradoritic

rock, owing to a mixture with  $MgTiO_3$ . The alumina left in the final concentrates combines particularly with the magnesia, thus forming spinel, the formation of which is favored by the relation-deficiency of silica in the magma. This mineral occurs in the following ore-types: the magnetite-olivinite (Ransberg); the ilmenite-norite (Ekersund); and the magnetite-spinellite (Routivare, Hellevig, Lofoten, and Stjernö). Vogt has called attention to the fact that the Mg-percentage increases in the first stage of concentration and then diminishes. While the original magma contains more  $Al_2O_3$  than  $MgO$ , the case is quite the reverse in the earlier stages of concentration. In the final product, however, the amount of alumina again exceeds that of magnesia.

Besides, the aforesaid substances, chrome and vanadium, which occur in small quantities, have undergone a concentration. The phosphorus, on the other hand, is not in general concentrated to any noteworthy degree. To this, however, there are exceptions, such as the segregations of ilmenite-norite traversing the labradoritic rock in the Soggendal-Ekersund field, which contain a fairly high percentage of phosphorus, while the surrounding rock carries little, and the above-mentioned concentrations, rich in apatite, in the hypersthene-gabbro at Krekling, Norway, and also in the nepheline-syenite of Alnö.

That silica, lime and alkalies occur in smaller quantities in the concentrates than in the rest of the rock-mass is manifested mineralogically by the total absence of feldspar from these concentrations.

Vogt has pointed out<sup>22</sup> that in several places in Lofoten and Vesteraalen, in the labradoritic rock containing olivine and hypersthene, there are besides segregations of magnetite-dialagite, also *schlieren*-like segregations of pure olivine rock as well as of hypersthene. This shows that in the same magma differentiation processes following different lines have taken place nearly contemporaneously. As extreme basic segregations the limestones occurring in the nepheline-syenite may also be explained.

Many different attempts to suggest the cause of these differ-

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<sup>22</sup> *Zeitschr. f. prak. Geol.*, vol. xiv., pp. 217 to 233 (1906).

entiations have been made, but no satisfactory explanation has as yet been proposed.<sup>23</sup> It seems as if, with respect to this kind of segregations, the view according to which the magma is regarded as a mixture of different liquids, partly insoluble in one another, were decidedly preferable to the theory which considers the laws of dilute solutions applicable to the magma. The principle of limited solubility must be considered as the physico-chemical principle governing the differentiation-phenomena of silicate-magmas in general.

Neither "Soret's principle," nor any other form of the theory of diffusion, nor "connection currents," nor the magnetic attraction of the "liquid molecules," nor the different weight of the segregated solid constituents can afford an explanation of differentiation-phenomena of this kind. The geological conditions also seem to harmonize better with the view which connects the differentiation with the segregation and solidification of liquids insoluble in the remaining magma. These are separated out in consequence of the cooling of the magma, by which the conditions of solubility are changed, or of the escape of water or other mineralizers; the segregation takes place at first in the form of drops throughout the magma, which drops, on account of the surface-tension, have a decided tendency to coalesce and flow together into *schlieren* and larger concentrations. Which of the liquids is attracted to the side-walls and solidifies there, and which of them solidifies in the center, will in each case depend on the relative force of the adhesion to the side-walls.

#### *Analogous Deposits.*

Titaniferous iron-ore segregations in basic eruptive masses constitute a well-defined class, which has representatives in all parts of the world. Several of the different types found in Scandinavia occur in other countries also.

In the United States and Canada these ores have long been grouped together as a separate class, and a great many deposits of this kind have been described.

The magnetite-olivinite or Taberg type is analogous to the deposit at Iron-mine Hill in Cumberland, R. I., described by Wadsworth, though the latter is of smaller dimension. The

<sup>23</sup> Vogt, *Zeitschr. f. prak. Geol.*, vol. ix., pp. 327 to 340 (1901).

"gabbro titanite-iron-ores" of the Mesabi range in Minnesota, described by N. H. and H. V. Winchell, also seem to come very near to the type, though the concentration of the iron and the titanium has in these ores proceeded further. Among the segregations occurring in large masses in the various gabbro and labradoritic rocks of the eastern Adirondacks, the Taberg as well as the Ekersund type is represented.

Perfect analogies to the Ekersund type of ilmenite-segregations in labradoritic rock are offered by the Canadian ilmenite-deposits of Quebec and Ontario, which frequently contain from 30 to 40 per cent. of titanite acid and, in consequence thereof, a low percentage of iron. Some of these ores seem to consist of a mixture of ilmenite and titanite-magnetite with a diminution of the percentage of titanite acid and an increase of that of iron. The inclosing rocks are labradorite and norite.

Deposits analogous to the magnetite-spinellites of the Routivare type also occur in the United States—namely, the chemically closely allied magnetite-spinellite deposits, accompanied by corundum, in the norites of the Cortland series, described by G. H. Williams.<sup>24</sup>

To the titanite ores of the nepheline-syenites correspond segregations of quite the same character in the rock-series of Magnet Cove.<sup>25</sup>

#### *Utilization.*

From the above it appears that the Scandinavian countries inclose very large supplies of iron-ores of this kind, and that, in reality, some of these deposits, such as Taberg, Routivare, Ekersund-Soggendal, etc., are among the largest iron-ore deposits in Sweden and Norway. Numerous attempts at exploiting them have been made in different parts of the two countries. Taberg has given rise to a local iron industry on a small scale carried on during two centuries. The ores of Ulfö have been used in several blast-furnaces in Norrland; from Ekersund-Soggendal during a succession of years ore was exported to

<sup>24</sup> "The Iron-Ore and Emery in the Cortlandt Norites," in Norites of the "Cortlandt Series," on the Hudson River near Peekskill, N. Y., *American Journal of Science*, Third Series, vol. xxxiii., p. 194 (1887).

<sup>25</sup> H. S. Washington. Igneous Complex of Magnet Cove, Arkansas, *Bulletin of the Geological Society of America*, vol. xi., pp. 389 to 416 (1900).

England and smelted there; numerous minor mines scattered all over Sweden and Norway bear testimony to the attention which these deposits have attracted. However, all these attempts have been given up because of the unfitness of the ores for metallurgical purposes, which is also the cause why all or nearly all other titaniferous iron-ores all over the world lie unworked.

#### GROUP IV.—THE IRON-ORES OF THE METAMORPHOSED CAMBRO-SILURIAN SCHISTS.

These ores, which form a very well-defined geological class, are also territorially confined to a certain "ore-province." They occur exclusively within the area of more or less metamorphosed schists which forms the greater part of the mountain-districts of the Scandinavian peninsula north of the 65th degree of latitude. Through the abrasion of the Atlantic and the erosion the ore-bearing horizons have in places been laid bare; these ores are therefore almost exclusively confined to the Norwegian coast and the valleys penetrating into the country from the sea. The fjord-valleys deeply indenting the coast, as well as the nearest islands, are rich in deposits of this kind.

These ores have long been known, but, in spite of the favorable situation of several of the larger deposits on or near the Atlantic, they have been exploited, either not at all or to very small extent, by reason of their low percentage of iron. Only since the introduction of magnetic ore-concentration have attempts been made to utilize them for export on a larger scale.

#### *The Geological Horizon.*

The metamorphic schists in which these ores occur form a mighty complex of argillaceous and quartzite schists, gneisses, limestones and dolomites. Vogt has proposed to divide them into the Sulitelma schists, the younger gneiss group, and the mica-schist-marble group.

The whole of this series of strata has the character of a shallow-water formation, while the absence of conglomerates, the regular stratification, and the horizontal persistence of the rock-members, evidently prove that littoral formations do not enter into its composition. On the other hand, the abundantly thick limestones, and the more quartzose than argillaceous



character of the schists, indicate that it is not a deep-water formation.

On the whole, one may distinguish in this rock-series an easterly, more phyllitic facies, which lies chiefly on the Swedish slope of the Scandinavian highlands, and a westerly facies, which, owing to the dynamo-metamorphic agencies accompany-

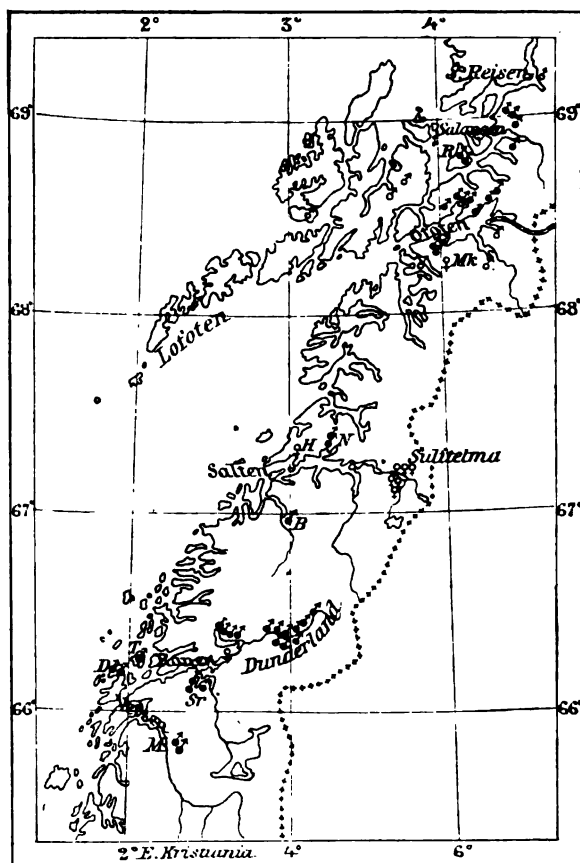


FIG. 19.—DISTRIBUTION OF ORE-DEPOSITS OF METAMORPHOSED CAMBRO-SILURIAN (Vogt).

ing the rock-lication, has received a more crystalline character. The degree of this crystalline character varies very rapidly, also, in a vertical direction. Thus the rocks of the so-called younger gneiss group show throughout a more crystalline development than the underlying schists of the mica-schist-marble group.

From fossils, chiefly found in the less metamorphosed schists on the Swedish side, all these formations have been shown to be of Paleozoic age. Also, in the vicinity of Sulitelma, on the very border between Sweden and Norway, fossils (encrinites) have been met with in a limestone, which occupies a lower level than the schists of the Sulitelma complex. These discoveries of fossils do not, however, afford an exact determination as to the age of the series.

The rock-folding within this area began in Silurian time, and continued long, ere it was completed during a post-Silurian, perhaps a post-Devonian, period. In connection with the rock-folding, there occurred great intrusions of igneous rocks in the form of laccolites, sheets and dikes. The intrusions are represented by basic as well as acid eruptive rocks, in composition ranging from peridotites, olivine-gabbros and other gabbro-rocks to light-colored granites rich in soda, forming together a rock-series of obvious "consanguinity."

Within this sedimentary complex the iron-ores occupy several horizons in the central and upper parts of the mica-schist-marble group. The ores seem exclusively to accompany the limestone and dolomite, an association which forms one of their most characteristic geological features. The known deposits of this class occur between Vefsen as the southernmost locality (about 65° 50' N. Lat.) and Sydreisen in the province of Tromsö (69° 10' N. Lat.), along a line of about 450 kilometers.

#### *Dunderland.*

The most important and best known of the deposits of this class are those of the Dunderland valley, which runs NE. from the interior end of the Ranen fjord. The Arctic circle crosses these deposits, which are distributed along a line of more than 40 kilometers.

The relations of the Dunderland field are somewhat complex, and have not, as yet, been sufficiently investigated. On the whole, the strata of the mica-schist-marble group are found in the bottom of the valley and the younger gneiss in the surrounding heights. But the details are much more intricate than Vogt's schematic representation<sup>26</sup> suggests. The inclination of

<sup>26</sup> Dunderlandsdalens Jernmalmsfelt, *Norg. Geol. Unders.*, No. 15 (1894), and *Det Nordlige Norges Bergverksdrift*, 1902, *Zeitschr. f. prakt. Geol.* vol. xi., pp. 24 to 28, 59 to 65 (1903).

the strata varies considerably; a change of the dip from nearly horizontal to highly inclined or vertical is observable within short distances. Owing to a strong plication the same ore-bearing layer will occur reduplicated, and the thickness of the limestone-beds is multiplied. Laccolites and sheets of light granite occur in many places between the stratified rocks without exercising any influence on the character of the ores. In general, this iron-formation, which may be regarded as a member of the stratified rocks, does not occur close to the limestone or dolomite, but is separated from it by a layer of barren schist up to a few meters in thickness.

The iron-formations may be followed for several kilometers without interruption; their thickness may amount to 100 m. or more, but sometimes diminishes to less than 10 m. Their contacts are sometimes sharply defined, but frequently the iron-formation passes gradually into the surrounding schists.

The iron-formation consists of the usual mineral constituents of the quartz-schists—*i. e.*, mainly of quartz and light mica, with which specular hematite (generally scaly) and magnetite are associated. Green pyroxenes and amphiboles are generally present, besides occasional epidote and garnet. The iron-percentage varies; the rock graduates on one side into the usual schist nearly free from iron, on the other into the richer ore-concentrations. Generally speaking, the iron-percentage varies between 15 and 40.

Within these primary ferriferous formations occur the richer iron-deposits which may be regarded as ores. In a few places these have attained an iron-percentage of about 55. This is, however, exceptional. Generally, the ore contains about 40 per cent. Since only about one-third of the iron occurs as magnetite, magnetic concentration is difficult.

Barren portions of the common quartzitic schist frequently occur inclosed in the ore. The ore contains the same secondary minerals as the iron-formation and in greater quantity. Only exceptionally is it mixed with lime.

The area of the outcrops of the workable deposits in the part of the field belonging to the English company, the Dunderland Iron Ore Co., is stated to be 577,000 sq. m. In this computation, however, part of the less rich iron-formation seems to have been reckoned in, and an iron-percentage of 32.5 some-

times included. The average iron-percentage is said to be 38.6, and the quantity of ore that can be extracted by open cuts above the level of the valley is estimated at about 89,000,000 tons.

The greater part of these considerable ore-deposits was acquired in 1902 by the above-mentioned English company with a view to producing, by magnetic concentration, after the system of Edison, briquettes carrying 65 per cent. of iron from the 38 per cent. ore. At the same time the percentage of phosphorus is to be reduced from 0.2 to 0.3 to obtain an ore suited for the acid Bessemer process. In 1906 a railway from the mines to the harbor, concentration-works for nearly 500,000 tons of crude ore per annum, etc., were completed, but the export of the product had not commenced.

#### *Naeuverhaugen.*

Among the iron-ore deposits of this class the Naeuverhaugen field was the first that attracted attention. As early as about 1875 it was an object of several investigations both from a practical and a scientific point of view.

Naeuverhaugen is of far smaller dimensions than Dunderland. However, its longitudinal extent is considerable, about 8 km. The general thickness of the ore-beds is only about 2 m.; exceptionally, it amounts to 10 m. or more. The whole ore-area has been estimated at 10,000 sq. m.

The ore of the Naeuverhaugen field consists mostly of specular hematite. As, consequently, a magnetic enrichment would be difficult to perform, attempts for concentration in the wet way have been made, though without decided success. The field lies unworked.

#### *Salangen.*

The ores of this class occurring north of the fjord of Ofoten belong to a type different from the ores of Dunderland and Naeuverhaugen; they consist chiefly of magnetites and, moreover, contain manganese. For the rest they show a similar mode of occurrence—viz., in regular strata and associated with limestones. An instance of this ore-type is offered by the field of Salangen, which has lately become the object of exploitation.

In the Salangen field the mica-schist-marble group is composed of quartzite-schists nearest to the fjord of Salangen,

overlaid by mica-schists with garnet and amphibole, and with mighty interstratified limestone-beds. The ordinary light granite occurs as laccolites and sheets conformable to the stratification; in places one can observe how it is strongly impregnated with magnetite, which has been derived either from the schists at the time of the injection or by a secondary infiltration; a highly altered peridotite also occurs.

In several places considerable disturbances of the stratification occur in the form of inversions and plications. The ore-bearing formation almost always accompanies the limestone, and generally occurs in the schists quite near the limestone.

Contrary to the case at Dunderland, the ore in the field of Salangen consists mainly of magnetite. Experiments have proved that from three-fourths to nine-tenths of the iron-percentage can be magnetically concentrated. Minor beds of specular hematite in limestone occur. The iron-percentage generally varies in the ferriferous formation between 15 and 50. The richer parts, with 40 per cent. of iron or more, are of comparatively small extent, and the ore can be shipped and used only after magnetic concentration. The ore is characterized by a percentage of manganese generally varying between 4 and 6 per cent., but sometimes amounting to 14 per cent. The percentage of phosphorus is about 0.2, the ordinary percentage in these deposits.

In the ore occur the common gangue-minerals, amphibole, epidote and garnet. The structure of the ore varies. Sometimes it is compact, coarse-grained and without parallel structure, as in the deposits of Storhaugen, probably derived by replacement of limestone. The ores which occur in the schists show the same structure as these.

The iron-ore field of Salangen was acquired at the end of 1906 by a German company, which intends to concentrate the ore and make it into briquettes after Gröndahl's method.

#### *Other Deposits.*

A great many ore-fields of this class occur within the area defined above. They differ, however, in minor points from those described. At Dolstadsåsen in Vefsen, the ore, which consists mainly of magnetite, occurs associated with amphi- ..

bole, garnet, epidote, alternating with schists rich in amphibole between thick limestone-beds.

At Fuglestrand occurs a ferriferous formation in the form of schists rich in amphibole and epidote. Both magnetite and specular hematite occur. There are reasons for the assumption that the considerable development of iron-silicates characterizing the iron-formation of Fuglestrand depends on the abundant intrusion in this field of granite, which occurs as sheets parallel to the stratification as well as in the form of laccolites.

In the islands of Dönnösö and Tomö similar deposits have been the object of some exploratory work.

The Ofoten ore-deposits extend both on the northern and the southern side of the fjord. They belong to a basin-shaped complex of strata, cut transversely by the fjord. The tectonic conditions here are very clear. At the bottom of the mica-schist-marble group lies a thick bed of limestone, accompanied by the ferriferous formation, which on the south side of the fjord is strongly compressed, forming a basin with the axis of plication dipping towards NE. As youngest member occurs the younger gneiss. The Ofoten ores belong to the manganiferous type; the manganese is, however, very unequally distributed; it may amount to 10 per cent. The thickness of the ferriferous formations on the Ofoten exceeds only exceptionally 10 m.; in one place, however, a thickness of more than 50 m. is reported.

North of the fjord of Ofoten the same ferriferous formation is known in numerous places in the province of Tromsö. Besides the above-mentioned Salangen field, ores of this kind occur in the fjord districts of the Gratangen and the Lavangen, and in the islands of Rollö, Andorgö and Dyrö, where one and the same stratum forms flat basins, everywhere with iron-ores in the outcrop.

### *Summary.*

The deposits of this group belong to a ferriferous formation of vast horizontal extent, occupying nearly the same geological horizon in the series as the mica-schist-marble member of this sedimentary series. The ferriferous formation occurs regularly associated with limestones, in most cases, however, in the schists underlying the limestone. The connection with the

limestone is so strongly marked that in certain districts nearly every limestone-bed is accompanied by iron-ore; some observers have even been inclined to assume a connection between the thickness of the limestone-beds and the size of the iron-ore deposits.

Mineralogically, the ores are characterized as mixtures of magnetite and specular hematites; and, further, by the occurrence of iron-magnesia-lime-silicates of the amphibole, augite, epidote, and garnet groups. Quartz is always present in large quantity. Chemically, these ores are characterized by a high percentage of silicic acid, low percentages of CaO, MgO, and Al<sub>2</sub>O<sub>3</sub>, a medium percentage of phosphorus, and small amounts of sulphur and titanitic acid. Whether these ores are primary sedimentary deposits or secondary concentrations of leaner iron-bearing formations is still an open question of the greatest practical importance.

These ores have, *e. g.*, in Dunderland, an extent of several kilometers in length and, at the same time, a considerable thickness. If, taking the syngenetic point of view, we regarded these ores as ordinary stratified formations, altered only by regional metamorphism, we would have to assume an extent of several kilometers in the direction of the dip. Such a conclusion might be highly misleading with regard to the ore-supply. As to the depth which the ores of this kind reach, there is as yet no practical experience, as neither exploratory work nor even any borings below the present or former ground-water-level have been performed.

A comparison with the Archæan ores of Group I. shows, it is true, some points of agreement. On the whole, the primary characters of chemical sediments are much more evident in this class of ores than in the Archæan ores. Above all, the transformations in the anamorphic zone are less marked; this is shown by the gangues being less developed and the alteration into magnetite less advanced. No analogies to the large magnetite-stocks among the Archæan ores are found here. Although the nearness to the magnesian limestone has offered plenty of material for the formation of lime-magnesian silicates of the pyroxene, amphibole and garnet groups, these silicates never are formed in such abundance as to compare with the *skarn* gangue of the Archæan ores. The interchange of con-

stituents between the schist, the iron-ore and the limestone, lying close to one another, has been rather limited. Probably also the submersion in the anamorphic zone did not go so deep as to reach a temperature high enough for the formation of anhydrous silicates on a large scale. The depth and the temperature under which the crystallization of these ores occurred seem to have been better adapted to produce the slightly hydrated silicates of the epidote group.

The transformations in the catamorphic zone also are less marked; one finds no concentrations of so great richness, no "sköl"-formations, and no accumulations of ores in pitching troughs or on impervious basements. The ores are of more equal leanness, and in general the concentration does not exceed 40 per cent. of iron.

On the whole, one may consider these deposits as the roots or the deepest, comparatively unconcentrated parts of regional metamorphosed chemical depositions, laid open by the deeply penetrating fjords and valleys of the Norwegian coast; the upper, probably more concentrated and richer parts of the same deposits, having been destroyed by erosion.

#### *Analogous Deposits.*

The ores of this class are in many respects comparable to those of the lower Silurian formation in the eastern United States, especially to those occurring in a belt from Vermont to Alabama. These ores occur only where the lower Silurian limestone and the Hudson shales meet, as the Norwegian ores always occur at or near limestones, sometimes dolomitized. This is, indeed, one of their most important geological characters. The Norwegian rock-strata are, of course, more metamorphosed, the rocks consisting of crystalline schists and marble or magnesia-limestone, and the ores being specular hematite or magnetite, instead of red and brown hematite. The Clinton ores likewise show, with regard to geological conditions, great agreement with the Norwegian Paleozoic ores.

#### GROUP V.—CONTACT-DEPOSITS IN THE CHRISTIANIA REGION.

These ores were considered by Keilhau, Daubrée and Kjerulf as genetically connected with the intrusion of granite in the



same region; and this opinion was afterwards confirmed by Vogt, who executed a minute survey of the deposits.<sup>27</sup>

### *Classification of the Rocks.*

According to Brögger, the igneous rocks of the Christiania region may be divided into seven groups of different age; the oldest three are more basic, and consist of (1) gabbro-diabases; (2) basic augite-, mica- and nepheline-syenites (laurvikite and laurdalite); and (3) quartz-bearing augite-syenite (akerite). Of later age is the following syenitic and granitic series, comprising (4) red quartz-syenites (nordmarkite); (5) soda-granites (grorudite); and (6) granite. As the youngest members occur dike-forming diabase and diabase-porphyrity. The eruptives are probably of Devonian, surely of post-Silurian, age. They occupy an area about 250 km. long, and in some places more than 100 km. wide.

The intrusives are bordered partly by Archæan rocks, partly by the Silurian strata, and by porphyry-outflows. The contact-deposits are found in all these different pre-granitic rocks.

Most of the deposits are connected with the red quartz-syenite (nordmarkite), some of them with the soda-granite (grorudite) and the granite.

### *The Ores.*

The iron-ores are, as a rule, mixed with true contact-minerals, such as different species of the garnet and vesuvian groups, scapolite, wollastonite and others. This is especially the case with the deposits occurring in the limestone and marly slates. In the clay-slate, chiasolite is found as contact-mineral. The percentage of iron is through the gangue reduced to from 30 to 35, and only exceptionally exceeds 40. The ores are generally strongly pyritic, but low in phosphorus and titanium. Frequently they occur in the immediate vicinity of the intrusive rock, but they may also be found up to one km. from the contact. In a few cases the distance from the visible contact is more than one km., but the ores never are found outside of the metamorphic zone of the contact. The majority of the deposits occur in the Silurian strata, partly at the borders of the Silurian rocks, partly in big metamorphosed Silurian rock-fragments, completely surrounded by the igneous rock. The

<sup>27</sup> *Zeitschr. f. prakt. Geol.*, vol. ii., pp. 177, 464, (1894), vol. iii., p. 154 (1895).

different Silurian horizons are equally impregnated with ores; and the clay-slates as frequently contain ore-deposits as do the limestones and marly slates. Also, the Archæan gneisses, and sometimes the porphyries, are ore-bearing.

The ore-deposits show generally a stratiform extension, and may be followed with varying thickness along the same bed for several hundred meters.

These deposits, though numerous, are quantitatively too insignificant to play any commercial rôle. In earlier times several hundred small ore-bodies were worked. The ore is mainly magnetite, but also specular hematite. Also, sulphides of iron and copper occur in so great amount that the ore may obtain the character of a copper-ore. Exceptionally, also, galena and blende have been found in such quantities as to be mined as ores. But all the deposits are small. From the seventeenth up to the latter part of the nineteenth century, they furnished a group of small blast-furnaces with iron-ores; and an insignificant copper- and lead-production was in early times based on these ores.

#### *Analogous Deposits.*

The ore-deposits of the Christiania territory are genetically most similar to the Pitkaranda deposit in Finland, and the known deposits of Schmiedeberg in Silesia and Berggiesshübel in Saxony.

There are a great number of deposits of this kind in the western United States, chiefly in Colorado and California, where they occur associated with the younger eruptives of the Rocky Mountains and the Sierra Nevada.

#### GROUP VI.—LAKE- AND BOG-ORES.

These ores formed the raw-material for the oldest iron-industry in Scandinavia, long before the blast-furnace process was known. For this reason, Carl Linnæus called them *Tophus Tubalcaini*, after Tubal Cain, the first blacksmith (Gen. iv, 22). The lake-ores occur in most provinces of Sweden and in the southern part of Norway. But their abundant occurrence is confined to regions where the ground consists of moraine and glacial gravel and sand, especially the high plateau of Småland, the northern parts of Vermland, Vestmanland and Dalarne, and the greater portion of Norrland. They occur only sparingly in the regions covered by glacial and post-gla-

cial marine-deposits, such as the lower coast-belt of southern Sweden, and the plains surrounding the great lakes of Vänern, Vettern, Hjelmaren and Mälaren. In short, the lake- and bog-ores are most frequent above the marine level of the glacial period. A certain connection with the distribution of the peat-mosses is indicated. On the other hand, the bog-ores are by no means more frequent in the districts rich in other iron-ore deposits. In some places, a connection with the greater pyrite-deposits may be suggested.

The bog-ores are recent formations, produced before our eyes. In lakes, where the ore has once been exploited, it grows and may be utilized again. In some lakes of Småland mining operations have been resumed at places exhausted 25 years before.

In the ore-bearing lakes, the iron is precipitated from dilute solutions chiefly along certain zones, parallel to the shores, at a depth of from 2 to 4 m., and the ores are thus distributed in belts on the bottom of the lake, to a thickness of at most 0.5 m. Lakes connected by a water-course frequently all contain bog-ores. In the upper lakes the ore is more fine-grained ("gunpowder-ore," "pearl-ore"), while in the lower lakes the ore has grown to coarser concretions ("money-ore," "cake-ore").

The purer lake-ores generally contain from 50 to 60 per cent. of  $\text{Fe}_2\text{O}_3$  and from 10 to 15 per cent. of water. Silicic acid is frequently mechanically intermixed, reducing the iron-percentage. Sometimes the ores contain a considerable amount of manganese (up to 20 per cent.). The percentage of phosphorus as well as of sulphur is generally high.

Bog-ores are often formed in lakes as lake-ores, and later, by a natural draining, brought above the water-level. But frequently bog-ores occur in a manner indicating their formation in the ground close to the surface; in such cases they are often formed in connection with peat-mosses.

The utilization of the lake-ores has in later years much decreased, and is to-day without importance. From 1860 to 1875 the annual production in Sweden was about 10,000 tons. From 1900 to 1905, it was only about 1,000 tons, varying from 300 up to 1,500 tons, according to the severity of the winters. The whole product comes from Småland and is used for the fabrication of cast-iron.

## **Quantitative Field-Test for Magnesia in Cement-Rock and Limestone.**

BY CHARLES CATLETT, STAUNTON, VA.

(Toronto Meeting, July, 1907.)

THE rapid development of the Portland-cement industry implies that the country is being very carefully searched for material suitable for its manufacture. Such material can be found at a great many places; but deposits thoroughly satisfactory in chemical composition, and at the same time meeting all the other requirements connected with the economic production and profitable marketing of the product, are exceedingly few, if I may judge from the investigations which I have had to make in a number of States.

The raw mixture which by its clinkering and grinding forms Portland cement contains approximately 75 per cent. of carbonate of lime. This is found in nature as limestone or marl. The natural rock commonly carries either more than the required percentage of carbonate of lime (in which case it has to be reduced by suitable admixture of clayey ingredients) or less—in which case purer lime carbonate has to be added. The controlling ingredient, therefore, is carbonate of lime, or limestone of the right composition.

Among the most serious difficulties is that of finding limestones low enough in magnesia to meet the exacting requirements of certain specifications. All engineers recognize that there is a limit beyond which it is not safe to let the magnesia go; but within that limit there is considerable difference of opinion. Until that difference is finally settled, no one would be willing to invest the large sum of money necessary for a Portland-cement plant, if it were not certain that the usual requirements in this particular could be satisfied.

The usual limit in well-established specifications is 5 per cent. of magnesium oxide in the finished cement, but many specifications limit the amount to 3 per cent. These figures

correspond roughly to 3.2 per cent. and 1.9 per cent., respectively, of magnesium oxide in the raw mixture.

It is comparatively easy with a little practice to detect magnesia to the extent of 10 or 15 per cent. The appearance of the stone, the way it effervesces with dilute hydrochloric acid, its hardness, etc., settle this question and enable us to eliminate a great many otherwise promising deposits. It is not possible to form by superficial examination any estimate of the amount of magnesia when it is as low as 5 or 6 per cent.; yet it would be hard to overestimate the advantage of being able to determine in a few minutes, and at a point remote from a laboratory, whether a material will probably produce a cement well within the limits in this respect, and whether one is justified in securing options and taking detailed samples for further investigation. The value of such a determination would not be destroyed by the fact that it was not exact, since the purpose of a preliminary investigation would be fully met if a difference of 1 per cent. in magnesia could thus be clearly and easily detected. It would then be possible to eliminate those rocks which contained decidedly too much magnesia, and to retain, for further and more exact laboratory investigation, those which were very low in magnesia, or might possibly be low enough to meet the requirements of the case.

As the result of considerable investigation, undertaken with a knowledge of the conditions involved, my assistant, Mr. J. J. Porter (a member of the Institute, and recently elected associate professor of metallurgy at the University of Cincinnati), worked out the following method, which I have personally found valuable in this connection. The method is based on the fact that while calcium hydrate is very soluble in a solution of cane-sugar, magnesium hydrate is only slightly so. This gives us a means of precipitating magnesia in the presence of lime.

*Reagents.*—1:1 hydrochloric acid: 1 volume hydrochloric acid of 1.20 specific gravity plus 1 volume of water. A 30 per cent. solution of potassium hydrate: 30 g. of potassium hydrate (pure by alcohol) to 100 cc. of water. This must be free from carbonate. Sugar-solution: A cold saturated solution of granulated sugar. Calcium carbonate: C.P. precipitated. Standard limestones as needed, powdered to 40-mesh size.

*Apparatus.*—A small steel mortar for powdering samples; small sieve, 40-mesh size; measuring-spoon, holding between 0.4 and 0.5 g. of 40-mesh limestone powder, level full; 12 test-tubes with mark at 10 cc.; stand to hold 12 test-tubes in two rows of 6 each; a pipette, 1.75 cc., for HCl; a pipette, 1.5 cc., for sugar-solution; a pipette, 1 cc., for potassium hydrate; 6 small funnels; filter-papers to fit, uniform size; test-tube holder; alcohol-lamp; water-bottle; test-tube brush.

*Method.*—Crush sample, powder in mortar, and sift. Pour the powder into measuring-spoon and level off by knife-blade or card. Transfer the measured portion to test-tube.

Add from pipette 1.75 cc. of HCl, and, when effervescence has nearly ceased, boil for a moment. Then add enough pure calcium carbonate to neutralize the excess of HCl. Boil until steam issues freely from the mouth of the test-tube, in order to drive out all carbon dioxide. Add water to the 10-cc. mark, and mix thoroughly by shaking the test-tube.

In another test-tube, place, by means of the proper pipettes, 1.5 cc. of sugar-solution and 1 cc. of potassium-hydrate-solution, and dilute with water to the 10-cc. mark. Mix by shaking. Then filter the solution of the stone, allowing the filtrate to run into this alkaline sugar-solution. If magnesia is present, a precipitate of magnesium hydrate will form at the line of contact of the two solutions. After the filter has drained, these solutions should be mixed by inverting the test-tube.

The density of this precipitate is roughly indicative of the percentage of magnesia in the stone, and by comparison with standard stones run in parallel this percentage can be estimated pretty accurately, the probable error not being greater than 20 per cent. of the amount of magnesia present. As in all comparison methods, some practice is necessary to insure satisfactory determinations. Since the magnesium hydrate is not entirely insoluble, and some magnesia is apt to remain in the insoluble portion of the sample, the results are low. This probable error is desirable, since it is better to send samples to the laboratory for further examination than to discard something which might be satisfactory.

*Notes and Precautions.*—The fineness of the material affects the weight held by the measuring-spoon and also the ease of solution—hence the need of sifting.

There should be sufficient HCl to dissolve thoroughly all the carbonates of the rock; and this condition is assured if the resulting solution is yellow from ferric chloride. At the same time, it is desirable to have the smallest possible excess of HCl, because the presence of the alkaline chlorides decreases very materially the delicacy of the test.

The object of adding calcium carbonate is two-fold. It precipitates the iron; and it creates a condition of uniformity as to the neutrality of the solution which is very essential for comparative results.

It is desirable that all the filter-papers used in a series of tests be of uniform size and quality of paper, so that they may retain a uniform amount of the rock-solution.

The method of adding the reagents is important, and should be closely followed.

After trying various methods, the one given above has been found to give the most satisfactory results, both as to delicacy and reliability. It is, of course, essential that the potassium hydrate contain no carbonate, and it should therefore be occasionally tested with barium hydrate or with a solution of lime in sugar.

The magnesium hydrate precipitate frequently comes down with a greenish color. The cause of this is uncertain; but it is most prominent in those samples containing organic matter. Possibly it is due to a trace of ferrous iron produced. This color causes the precipitate to appear somewhat more dense and opaque, and, therefore, should be allowed for in making comparisons. With a little practice this is not difficult, particularly if the comparison is made by transmitted light.

The scheme outlined above does very well for rocks carrying up to 4 per cent. of magnesium oxide. Above this, the precipitate gets too dense for comparison without further dilution.

It is desirable that the pipettes should be made from glass tubes of different sizes, and that short pieces of rubber tubing should be attached as mouth-pieces.

All of the apparatus can be conveniently packed in a box of the inside dimensions of 10.5 by 7 by 6.75 in.

A double top, in the form of a shallow box, of a size to fit snugly in the larger one, may be used as a convenient recepta-

cle for the test-tubes, serving by means of auger-holes as a test-tube stand.

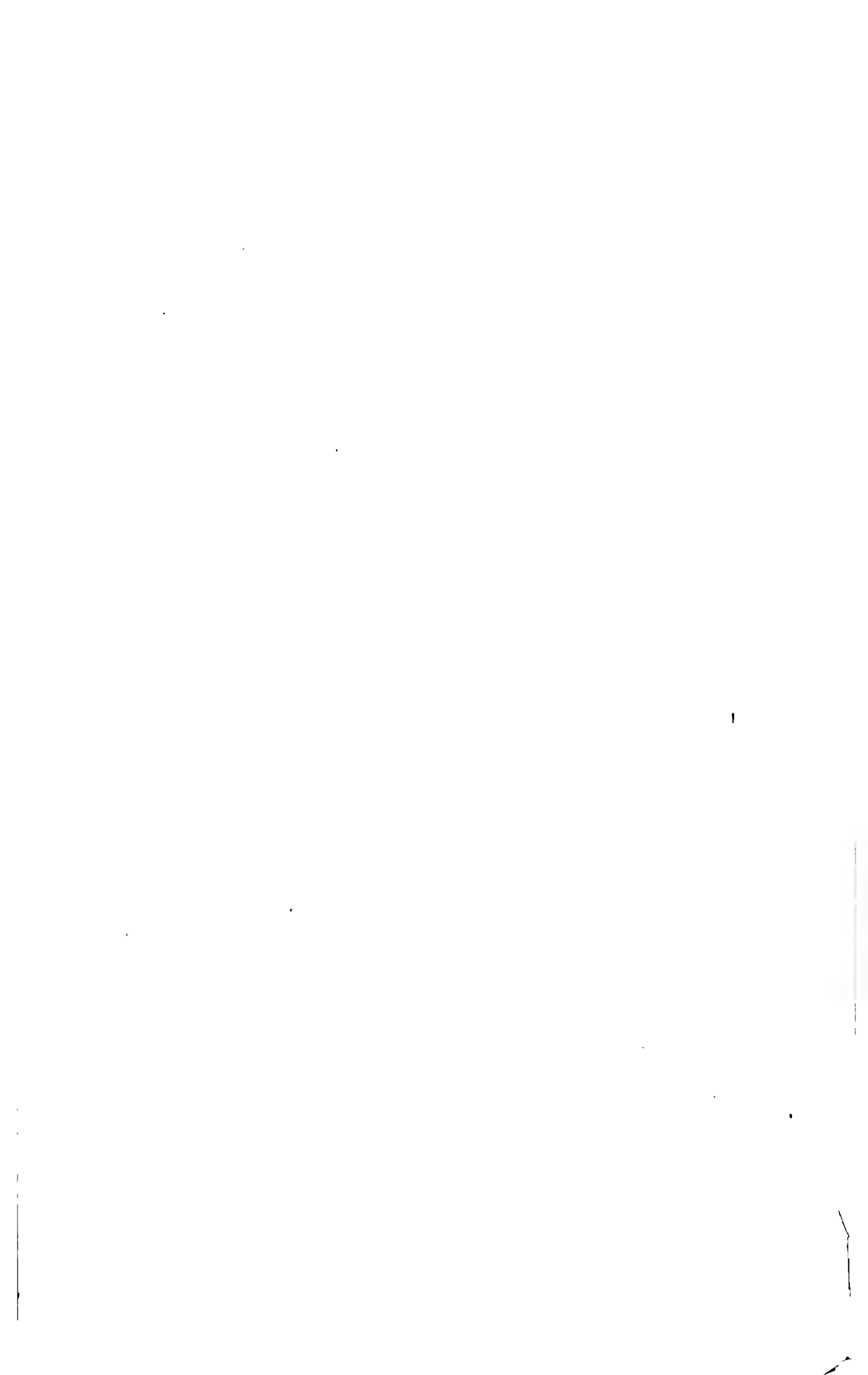
Small splinters from the larger pieces making up the permanent sample may be taken for this examination, and can be crushed without danger of loss by direct pressure and a grinding motion rather than by blows.

Such small pieces, if treated with dilute acid in a test-tube, will usually disintegrate entirely if the carbonate of lime is considerably in excess of the theoretical requirement, thus indicating the need of the admixture of clay or shale for the manufacture of cement.

If the action of the acid ceases before all of the carbonate is dissolved, and recommences when the splinter is rubbed so as to remove the clayey covering, the stone is apt to need the addition of purer limestone to produce a satisfactory mixture.

If the splinter retains its shape when treated with dilute acid, but all of the lime carbonate is dissolved, the stone probably approaches closely a natural Portland-cement mixture.





## **Geology of the Virginia Barite-Deposits.**

BY THOMAS LEONARD WATSON, BLACKSBURG, VA.

(Toronto Meeting, July, 1907.)

### **I. HISTORICAL.**

BARITE has been mined for many years in various parts of Virginia, probably the earliest mining-operations being in Prince William county, within 600 ft. of the Fauquier county line, about 4 miles south of east from Catlett, a station on the Southern Railway. It is claimed that the mineral was mined here as early as 1845.

Mining-operations in Campbell and Pittsylvania counties in the Piedmont region, and near Marion in Smyth county, in the southwest Virginia Valley region, were begun about 80 years ago. The mining and milling of barite on a commercial scale in Tazewell and Russell counties are more recent, and commenced about 15 years ago.

### **II. GEOGRAPHICAL AND GEOLOGICAL DISTRIBUTION.**

Barite occurs in many counties in the State, as shown in Fig. 1, but the industry has been confined to only a few of them. Its occurrence is noted in two of the three major divisions of the State—namely, the Piedmont region east of the Blue Ridge, and the Paleozoic area west of the Blue Ridge. In the Piedmont region the mineral has been mined in the following counties: Bedford, Campbell, Louisa, Prince William, and Pittsylvania. In the region west of the Blue Ridge, composed of Paleozoic sediments, barite has been mined in Montgomery, Russell, Smyth, and Tazewell counties. Of the counties mentioned, Bedford, Campbell, and Pittsylvania of the Piedmont region, and Russell, Smyth, and Tazewell of the Valley region, have been the principal producers. In 1906, operations were confined to five counties—Bedford, Louisa, Pittsylvania, Russell, and Tazewell—but in the first two counties named there was no production, the work being solely development.

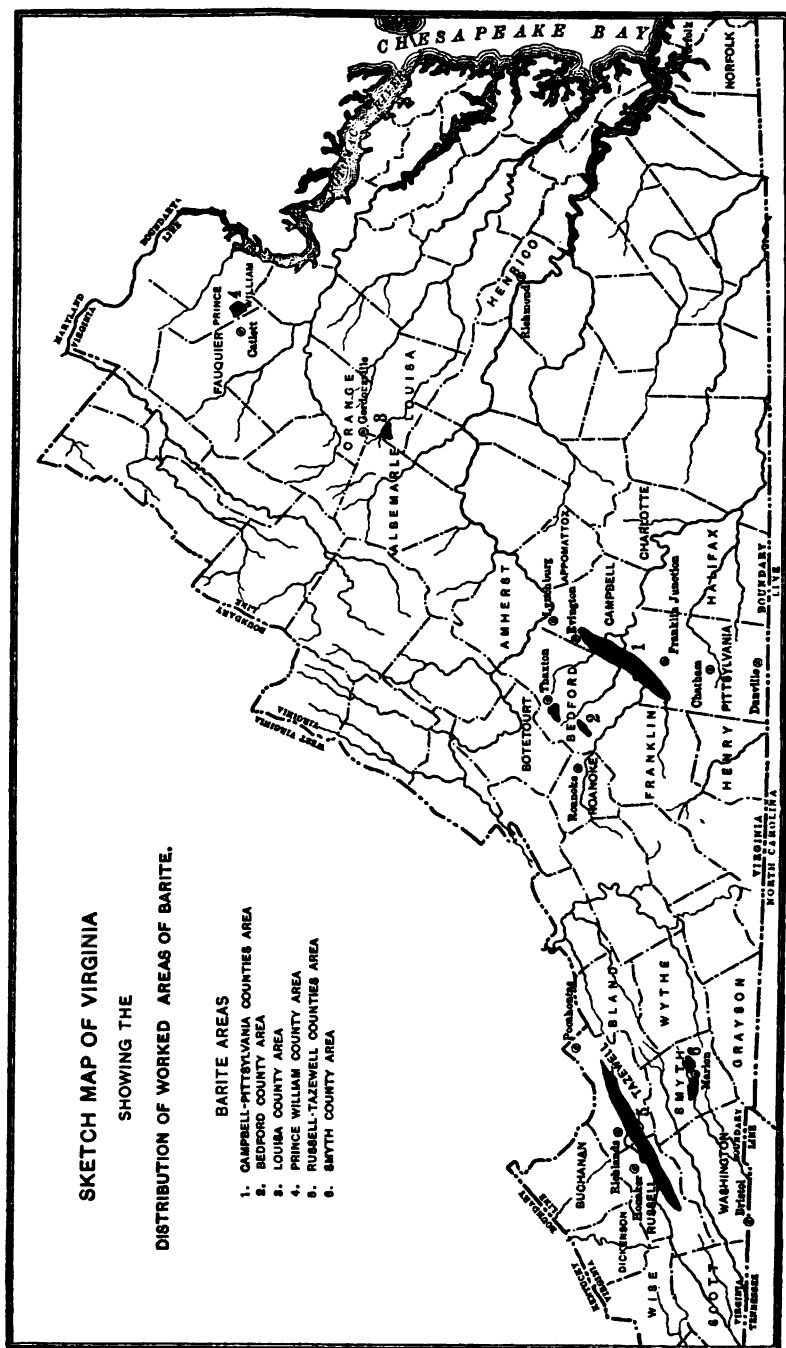


FIG. 1.—SKETCH-MAP OF VIRGINIA, SHOWING BARITE-AREAS.

Geologically, the barite-deposits of Virginia may be grouped into three unlike areas: (1) those deposits of the red shale-sandstone series of Triassic age; (2) those of the crystalline metamorphic area, the age-relations of the rocks being unknown, but probably pre-Cambrian for the most part; and (3) those of the Valley region, associated for the most part with the Cambro-Ordovician limestone (Shenandoah or Valley) or its residual decay. Areas (1) and (2) compose the Piedmont province, which stretches eastward from the Blue Ridge to the fall-line or the western margin of the Coastal Plain sediments.

### III. GENERAL MODE OF OCCURRENCE.

The Virginia barite-deposits of commercial importance thus far developed, which have been worked for barite alone, are associated with limestone as pockets or lenticular masses, largely in the nature of replacements, and as vein-like masses filling fractures in the limestone. In southwest Virginia and elsewhere in the Valley region where the barite occurs in the limestone, it is often found as superficially loose lumps and nodules of irregular shapes and sizes imbedded in the residual clays derived from the limestone. In several instances the barite is not associated with limestone, but occurs directly in siliceous crystalline rocks removed, so far as we know, some distance from limestone. The barite-deposit near Thaxton, in Bedford county, best illustrates the occurrence of barite in siliceous crystalline rocks remote from limestone-masses.

In Campbell and Pittsylvania counties of the crystalline area the barite is intimately associated with coarsely crystalline limestone (marble) and its residual decay. The local differences in the mode of occurrence of barite in Virginia are best brought out in the description given below of the three geologically-unlike areas in which deposits are found.

### IV. THE TRIASSIC AREA.

As yet only one deposit of barite of commercial importance has been developed in the numerous areas of Triassic rocks occurring in Virginia east of the Blue Ridge. About 4 miles south of east from Catlett station, in Prince William county, and within 600 ft. of the Fauquier county line, barite has been mined at different times since 1845. It was last worked in

1908, with a production of 1,500 tons of ore. The opening of this deposit probably marks the first mining of barite in Virginia.

The ore was mined by shafts and open cuts, the greatest depth reached in mining being 108 ft. The grinding and preparation of the ore for market were conducted in a mill built for that purpose on the property. This mill was afterwards burned, and in its place now stands a partly-completed crushing-house, located near the main shaft.

The area forms a part of the eastern Piedmont region, characterized topographically by a gently undulating surface, without marked relief. The geological position of this deposit is within the eastern margin of the red shale-sandstone series of the Triassic area which crosses the Potomac river west of Washington and terminates about 10 miles south of Culpeper, the Virginia portion of the New York-Virginia area as defined by Russell.<sup>1</sup>

The rocks of the immediate barite locality consist of ferruginous red sandy shales and a light-colored crystalline limestone. Measured at numerous points west of the mine the dip varies from 10° to 15° west of northwest. Between Catlett station and the mine the shales are penetrated by occasional masses of diabase.

Much of the material composing the dumps at the mine is a limestone breccia, in which red shale fragments are cemented by an impure crystalline limestone. Fractures are frequent, and are filled with barite and occasionally with calcite-crystals. These facts suggest that the barite-deposit occupies a crushed or fractured zone in the Triassic sediments, induced probably by faulting, although no evidence for such is apparent on the surface. In view of these facts, and since faulting is a characteristic structure of the Triassic areas in Virginia and of the similar eastern areas in general, it seems reasonable to ascribe the brecciation in the Prince William county locality to this cause.

The barite is associated with both the red shales and the impure limestone, usually as a deposition-product from the solution which filled fractures in the red shale. The widest of the

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<sup>1</sup> Russell, I. C., Correlation Papers—The Newark System, *Bulletin No. 85, United States Geological Survey*, p. 20 et seq. (1892).

barite-filled fractures, reported to be from 4 to 8 ft., form the chief source of the minable mineral. The barite occurs also as thin tabular cleavable masses in the limestone. It is of good white grade, both finely and coarsely crystalline, massive, and, judging from the ore on the dumps, quite free from most of the common impurities, especially manganese. I did not have access to the shafts, but it is reliably reported that the association of ore with limestone increases with depth.

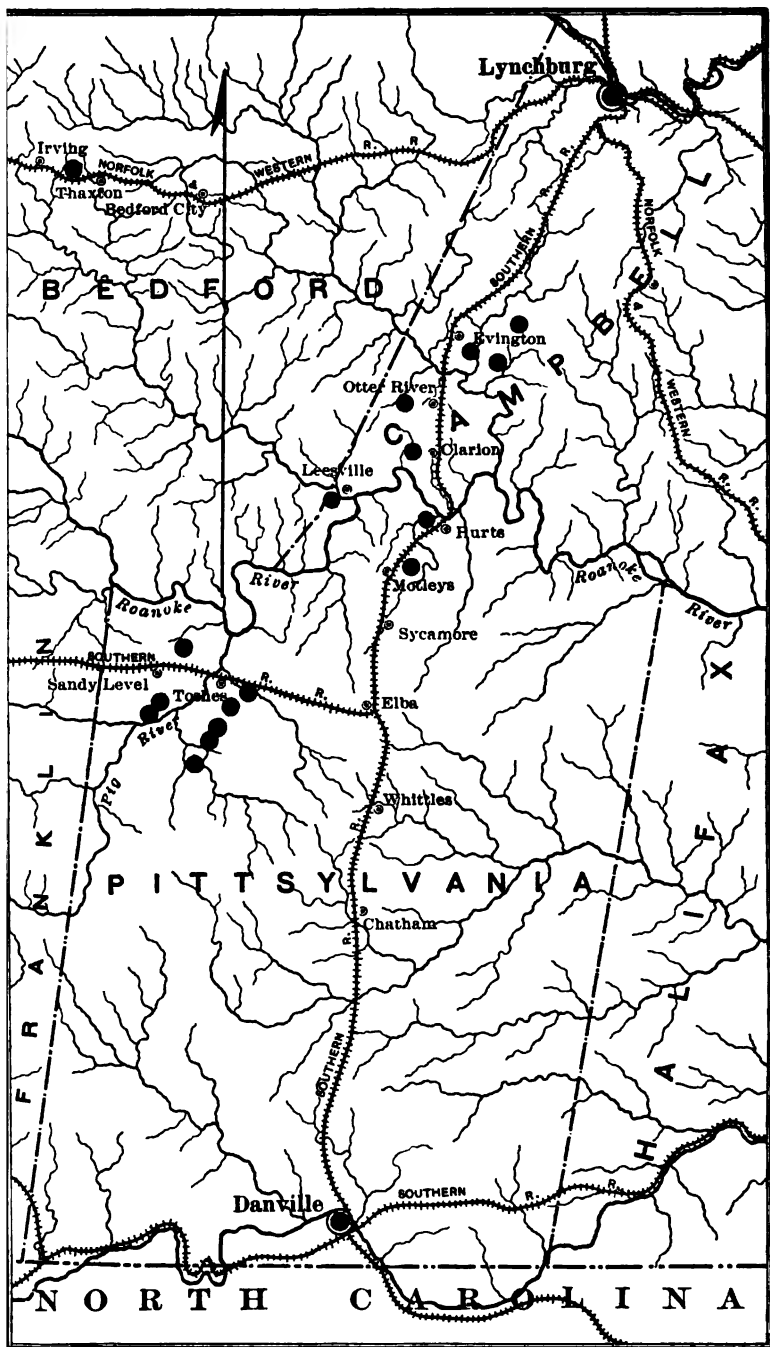
## V. THE CRYSTALLINE (PIEDMONT PLATEAU) AREA.

The Virginia-Piedmont province forms a part of the eastern crystalline region which extends southwestward from New York to northern central Alabama. Its limits in Virginia are from the Blue Ridge on the west to the fall-line, western margin of the Coastal Plain, on the east; and it widens southward. Excepting the Triassic areas the rocks are all crystalline, and comprise greatly altered sedimentary and igneous masses. The region is made up of a complex of schists, gneisses and granites, with, in places, interfoliations of slates, quartzites and limestones. This complex is further intersected by intrusions of basic eruptive rocks belonging, so far as they have been studied, to the diabasic, dioritic and gabbroic types. The bulk of the rocks composing this region, the oldest in the State, were mapped by the older geologists as Archean, but more recent studies reveal the fact that a part of them are as late as Ordovician.

The occurrence of barite has been noted in nine counties in the crystalline area, but the principal production has been from Campbell and Pittsylvania counties, with Bedford next in point of production. The ore has been mined in these counties for 30 or more years.

### 1. *The Campbell-Pittsylvania Counties Area.*

Beginning in the middle western portion of Campbell county, several miles east of Evinston and about 15 miles south of Lynchburg, a belt of barite-deposits is traced southwestward to 3 or more miles south of Sandy Level in the northwestern part of Pittsylvania county, a distance of about 50 miles. Numerous openings have been made at different points on the belt, many of which have been extensively worked and have pro-



● Barite.

Scale, 1 in. = 7.5 m. approximately.

FIG. 2.—BARITE-DEPOSITS OF THE BEDFORD-CAMPBELL-PITTSYLVANIA COUNTIES AREA.

duced large quantities of excellent ore. Fig. 2 is a sketch-map of the belt, showing the location of the various openings made.

This area, occupying a part of the middle western Piedmont region, presents no unusual features in topography from that of the Piedmont in general.

The most extensively-worked deposits on the belt are grouped about two centers, Evington in Campbell county, at the NE., and Toshes and Sandy Level in Pittsylvania county, at the SW. extremity of the belt. Operations were begun in the two counties within a short time of each other, with probably the Hewitt mine in the vicinity of Evington, which dates back to 1874, the first to open. The mines in the vicinity of Toshes and Sandy Level in Pittsylvania county were opened at least 25 years ago, and in both counties the mines have been operated almost continuously from the beginning.

(a) *Mode of Occurrence.*—Two characteristic occurrences of barite are observed in the Campbell-Pittsylvania area, always in association with each other, and equally as strongly emphasized in one part of the area as in the other. The first and principal occurrence is in intimate association with the crystalline limestone as irregular lenticular bodies or pockets, which measure from 100 to 200 ft. or more, replacing the limestone. At the Hewitt mine in Campbell county some of the barite-pockets were reported entirely inclosed by the limestone. The barite observes the same coarsely-crystalline massive structure as characterizes the limestone, and in several places gradation of the barite into the limestone was observed.

For the depths so far attained, there is immediately below and above the limestone, a variable thickness of a nearly black clayey mass, usually preserving the foliation of the original rock from which it was derived, and colored black from manganese oxide, derived from the decay of a limestone-schist. Through this black clayey mass are usually distributed, in irregular fashion, lumps and nodules of barite of large and small size. Occasionally, barite stringers of slight thickness are formed along the foliation planes of the clay. Figs. 3 and 4 illustrate the two occurrences of barite here described.

(b) *Associated Minerals.*—Calcite in the form of the coarsely-crystalline marble with which the barite occurs is much the most abundant associate. Pyrite and chalcopyrite are fre-



quently present as thin stringers, and as disseminated small grains and crystals in some of the barite; but more especially in the limestone. These are usually intermingled, and in several instances a green staining of malachite has been observed

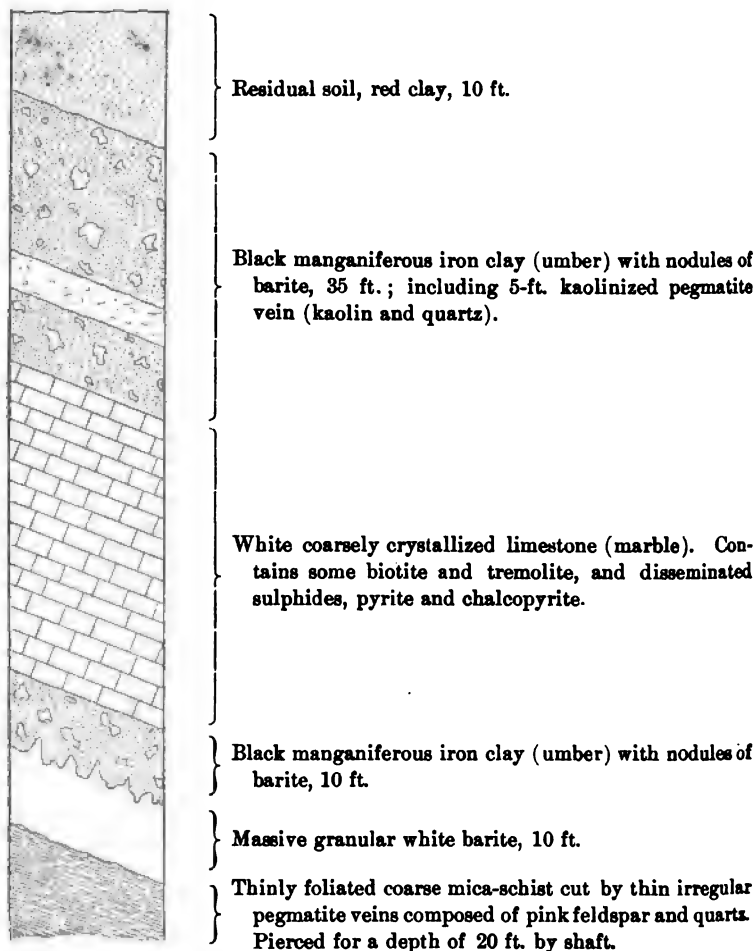


FIG. 3.—COLUMNAR SECTION, BENNETT BARYTES MINE, PITTSYLVANIA COUNTY.

from the alteration of the chalcopyrite. Manganese oxide and iron oxide are frequent associates in places, but, as a rule, they are not noticeable in the best grades of the barite. These are usually more abundant and, therefore, more troublesome in the barite mined from near the surface. A small amount

of the barite from the Hewitt mine in Campbell county is reported to have been highly charged with manganese oxide. Tremolite occurs both in the black clay and in the fresh crystalline limestone, and in places much biotite accompanies the tremolite in the latter. Biotite also occurs quite freely distributed through portions of the limestone in places not in association with tremolite.

(c) *Associated Rocks.*—The principal rocks of the Campbell-Pittsylvania barite-area are crystalline schists with intercalated thin beds of coarsely-crystalline limestone. The schists are of

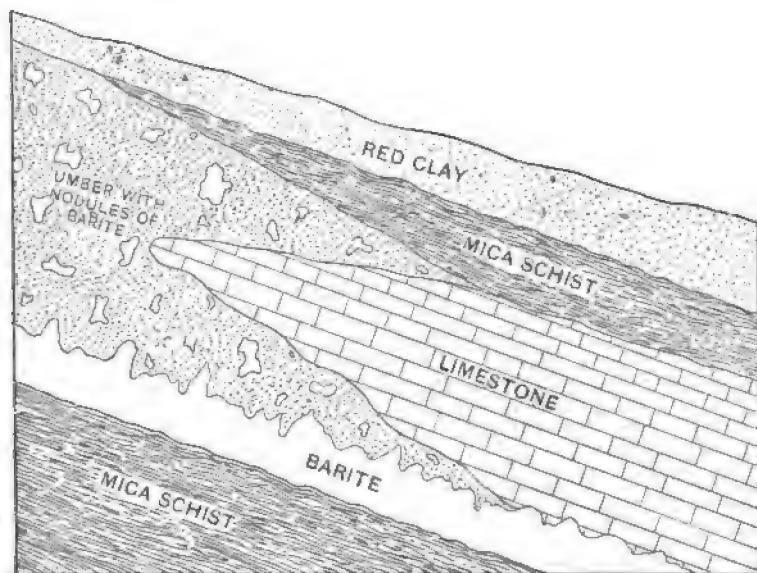


FIG. 4.—IDEAL SECTION IN BENNETT BARYTES MINE, PITTSYLVANIA COUNTY.

two distinct types—mica-schist and quartz-schist. The immediate rocks with which the barite is associated are marked by the essential absence of feldspar. The schists are composed of mica with minimum quartz, and they are unquestionably derived from sediments. Igneous rocks of basic composition occur in the vicinity of Toshes, and an irregular gneiss of granitic composition is found within 0.75 mile NE. of the Bennett mine, the origin of which, whether sedimentary or igneous, has not been determined.

In the Evington portion of the area, the underlying rock immediately in contact with the limestone-masses on the north-

west side is a fine-grained quartzite-schist of considerable purity, and containing small bright scales of white mica developed mostly along the planes of schistosity. The overlying rock immediately in contact with the limestone-masses on the northeast side is a variable mica-schist, always of fine texture and thinly foliated. Variation is from a moderately fine-grained muscovite-biotite schist at the Saunders-Phillips mines to a very fine-grained, lustrous, sericite-schist at the Hewitt mine. A fine-textured mica-schist, heavily charged with minute grains and crystals of black magnetite, forms an additional facies of the schist at the Hewitt mine. The mica-schists are composed essentially of mica without feldspar.

The mines developed on the southwest end of the belt in the vicinity of Toshes indicate an inclosure of the limestone-masses by a much coarser textured biotite-muscovite schist on the two sides. Feldspar is only recognized as a scantily-developed constituent of the rock, but thin stringers of quartz are interleaved at times with the schist, and small dike-like bodies of a coarse crystallization of pink feldspar and quartz frequently cut across the foliation of the mica-schist. The kaolinized equivalents of these dike-like masses are found in the same position in the residual clays derived from the schist.

Where exposed in mining, the limestone is a coarsely crystalline massive marble of considerable purity in places. In color it is generally white, occasionally pink, and sometimes greenish. It contains more or less of the silicate minerals, biotite and tremolite, and is frequently charged with pyrite and chalcopyrite. Manganese oxide and iron oxide are noted in places. The limestone is not of uniform thickness, but thins and thickens, the maximum observed thickness being about 60 ft. It conforms in dip and strike to the structure of the inclosing schists described above.

In composition the limestone is composed essentially of calcium carbonate with small amounts of magnesium carbonate, as shown in the analyses below, made by Dr. Walter B. Ellett, of specimens which I collected:

	1. Per Cent.	2. Per Cent.	3. Per Cent.
Insoluble matter, . . . . .	1.66	0.87	1.10
Alumina, } . . . . .	0.24	0.30	0.96
Iron oxide, }			
Barium sulphate, . . . . .	0.62	0.65	1.62
Calcium carbonate, . . . . .	89.36	93.33	91.07
Magnesium carbonate, . . . . .	6.61	2.82	3.73
Copper sulphide, . . . . .	trace	trace	0.36

- 1 and 2. White crystalline limestone from the Hewitt mine, Campbell county.  
 3. White and pink crystalline limestone from the Ramsay mine, Pittsylvania county.

A third and important type of rock intimately associated with the barite, and whose fresh equivalent is a limestone-schist, is a black manganiferous and ferruginous clay, locally called "umber." It is found at every opening made on the belt, and its position is next to the limestone, occurring, as a rule, on both sides. Openings made near the outcrop usually penetrate a considerable thickness of the black clay, but do not, as a rule, encounter the limestone. When followed down, however, for a short distance in the direction of the dip, the limestone appears inclosed on either side by the dark clay, which apparently thins on depth and ultimately disappears. Like the associated schists, the black clay always contains the foliation planes preserved in it of the original limy schist from which it was derived.

Leached mica-folia and small partly-oxidized areas of light green tremolite are found in the black clay of the Pittsylvania county mines. The relations of the clay to the limestone-masses and the mica-schist, together with its structure and composition, reasonably support the belief that it was derived by decay from a limy schist which was transitional between the well-defined limestone on the one hand and the mica-schist on the other. The kaolinized equivalents of the pegmatite dike-like forms found cutting the schists are observed in similar position in the black clay, as shown in Fig. 3. Much good barite is mined from the black clay, in which it occurs imbedded as nodular masses. Figs. 3 and 4 make clear the above relations of the clay to the limestone and the schist.

Samples of the black clay which I collected from the Bennett mine in Pittsylvania county, and analyzed by Dr. Walter B. Ellett, gave the following results:

	Per Cent.
Insoluble residue, . . . . .	14.20
Alumina, . . . . .	4.98
Ferric oxide, . . . . .	32.40
Manganous oxide, . . . . .	19.49
Lime, . . . . .	2.06
Magnesia, . . . . .	trace
Barium oxide, . . . . .	trace
Copper, . . . . .	trace

(d) *Structure*.—The rocks are all schistose and preserve a general NE. strike with local variations, which, so far as measured, range from N. 30° to 55° E. The pure limestone masses are more or less massive, becoming decidedly schistose with de-

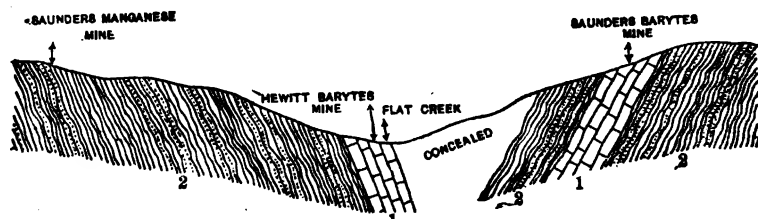


FIG. 5.—SECTION ABOUT 1.5 MILES EAST OF EVINGTON, CAMPBELL COUNTY.  
(Section About 3 Miles Long.)

creased purity. Greater variations are shown in the dip of the rocks.

At the northern end of the belt, near Evington, in Campbell county, at the Saunders-Phillips mines, the schists dip N. 60° to 65° W. At the Hewitt mine, which is about 2 miles S. 70° W. from the Saunders mine, the dip is toward the SE. and quite steep, affording a distinct synclinal structure, as shown in Fig. 5. Near the southern end of the belt at Toshes, in Pittsylvania county, the openings at the Bennett mine show a variable dip to the SE., which is much flatter than in the Campbell county area, the probable average being about 20°. Outcrops of the schist at other places in this vicinity gave concordant results in dip. As indicated in the measurements of dip on the two ends of the belt, the folding has not been of uniform intensity. At the northeastern end the folding is steeper and of a more closed type, while at the southwestern end it is flatter and of a more open type.

(e) *Mines*.—In Campbell county the principal mines are the Hewitt, Saunders, Phillips, and Anthony, grouped near together

and within a few miles east and SE. of Evington. Of these, the Hewitt mine has been the most extensively worked. It is located on the west side of Flat creek, about 2.5 miles from Evington, and about the same distance from the Saunders and Phillips mines. It was worked almost continuously from 1874 until 1904, when it was abandoned on account of water. It is developed by numerous shafts and drifts, the greatest depth reached in mining being about 160 ft. This depth extends below the local water-level, making it necessary to pump the water from the openings, which was troublesome, and finally led to suspension of work. The strike of the rocks is N.  $55^{\circ}$  E., with a steep SE. dip. The limestone with which the barite is associated has a thickness of about 60 ft., and is underlain by a quartzite-schist on the northwest side, locally designated the foot-wall, and overlain by a thinly foliated mica-schist on the northeast side, locally called the hanging-wall. As described above, the ore occurs, here and elsewhere in this belt, as irregular bodies replacing the limestone, and as irregular rounded nodules and masses in a black manganiferous and ferruginous clay, locally called umber.

The Saunders and Phillips mines adjoin each other, and are located on the crest of a well-defined NE.-SW. ridge on the east side of Flat creek, about 3 miles east of Evington. The developments comprise shafts, pits, and tunnels, the deepest one of which does not exceed 100 ft. The first openings were made about 20 years ago. The rock associations are identical with those described at the Hewitt mine. The strike of the schist is N.  $30^{\circ}$  E. and the dip N.  $60^{\circ}$ - $65^{\circ}$  W. About 2 miles SW. of the Saunders mine is the Anthony mine, which has produced a considerable quantity of ore.

The barite area in the extreme northwest corner of Pittsylvania county has been more extensively worked than any other part of the belt. It has been developed by a large number of mines, grouped in two nearly parallel belts on either side of Pig river, just south of its entrance into Roanoke river. Beginning at the northeast end the easternmost belt, trending approximately NE.-SW., has been developed by the following mines: Berger, Ramsay, Bennett, Parker, Thompson, and Dryden Wright. This belt lies approximately 0.75 mile east of Toses. The westernmost belt is developed by the Tom Wright

mine, 1 mile east of Sandy Level, and by the Hatchet, Meas, and Davis mines SW. of Sandy Level.

The Thompson mine is reported to have been the first one opened in the area; followed by the Parker, Berger, Bennett, and Ramsay, in the order named. The first four of these were worked more than 25 years ago, and the barite produced from each mine was very large in quantity and excellent in quality. Except the Bennett mine, which is operating at present, the others have been idle for some years, and very little could be seen at the time of my examination in September, 1906.

The mines in this area were developed by numerous shafts and drifts and some open work. The greatest depth yet reached in mining is 120 ft., the depth of the working-shaft at the Bennett mine. A description of this mine, one of the most extensively worked in the district, and the only one in operation in 1906, may be taken as typical of the area.

The rock-succession at the Bennett mine is shown in Fig. 3, which represents a vertical section of the 120-ft. shaft. As shown in this sketch, and also in Fig. 4, the wall-rock is coarse-grained, thinly-foliated mica-schist, intersected by pegmatite dikes composed of coarse crystallization of feldspar and quartz. The fresh mica-schist is exposed in the bottom of the shaft, where it is penetrated for a depth of 20 ft., the overlying rock being a black manganiferous and ferruginous clay, usually thinly foliated, and derived from a lime-schist. A similar black clay also underlies the limestone, occurring between it and the fresh mica-schist. The limestone, which is a coarsely crystalline marble and charged to a small degree with both sulphide and silicate minerals, is 40 ft. thick, and occurs between the two layers of black clay.

The barite is associated with both the limestone and the black clay, in part as a replacement of the limestone, and as irregular, rounded masses and nodules in the over- and under-lying clays. The largest concentration of the barite is between the limestone and the schist, and it has an average thickness of about 10 ft. The contact between the barite layer and the limestone is very irregular, the ore often penetrating far into the limestone, as shown in Figs. 3 and 4. The contact between the barite and the mica-schist is sharply contrasted with that made with the limestone, and is sharply defined and quite

regular. The barite is massive-granular, moderately coarsely crystalline, and of good white color. Five grades of the ore are made and marketed.

As indicated on map, Fig. 2, numerous other openings have been made between the Evington group of mines and the Toshes-Sandy Level group. Of these, perhaps the Maddox mine is one of the most important if not the most important. It is located about one mile SW. of Otter river station. Barite of excellent quality and in large quantity was mined, but the mine has not been operated in recent years on account of water, which makes the mining too expensive.

## 2. Bedford County Area.

Barite occurs and has been mined at a number of different points in Bedford county. Several mines near the Campbell county line have yielded large quantities of the mineral. In the western part of the county, between Bedford City and Roanoke, a recent operation shows an interesting occurrence of the mineral. The deposit lies about 3 miles NW. from Thaxton, and is reported to have been first opened in 1866, when a small quantity of the barite was shipped to Baltimore. It was re-opened again during the fall of 1906. The barite occurs in a completely-schistose coarse-grained granite filling a fracture. Some distance away from the fracture the granite is entirely massive and porphyritic, the feldspar phenocrysts being of large dimensions.

As nearly as could be determined, the fracture has a N.  $10^{\circ}$  to  $20^{\circ}$  E. course, and dips about  $60^{\circ}$  SE. An open cut about 20 ft. deep has been made along the course of the fracture for a distance of about 450 ft. The granite in the vicinity of the fracture is deeply decayed, although the fracture is distinctly shown at one end of the cut where it carries no barite.

The barite is crystalline, and varies in color from white to deep blue-gray. In places, much galenite in small grains and occasional sphalerite are disseminated through the barite. It seems quite probable that the source of the barium has been from the feldspar of the granite. The associated galena and sphalerite indicate that they were deposited contemporaneously with the barite. Whether they were introduced as soluble sulphides and deposited as such, or whether they were intro-



duced as sulphates and subsequently reduced to the sulphide form, there is no evidence.

### 3. *Louisa County Area.*

Barite occurrence and mining in Louisa county are limited to the Walker place, 0.75 mile south of Mechansville, and 3 miles south of east from Lindsay, the nearest railway-point. The openings comprise a number of test-pits and several shafts, the deepest one of which is between 70 and 80 ft. Mining had been temporarily suspended for several months prior to my visit and the openings were filled with water, which prevented entering them for study of the ore- and rock-relations.

The area, which forms a part of the crystalline region east of the Blue Ridge, is topographically a nearly flat, gently undulating surface, averaging about 500 ft. above mean tide-level.

The rocks are metamorphic crystalline schists of probable sedimentary origin. They are very thinly foliated micaceous schists, considerably altered, the foliation-planes of which are so regular and closely spaced as to be called, locally, slates. They strike approximately NE.-SW. and observe a general southeast dip, with a probable average of about  $45^{\circ}$ . Exposures of the rock are rare because of the considerable depth of residual decay, chiefly gray and red clays. Quartz-fragments, both large and small, frequently litter the surface, indicating quartz-veins or vein-like masses interleaved with and cutting across the foliation of the schists. Careful search failed to indicate the presence of limestone, and close inquiry further confirmed its absence.

Examination of the ore was necessarily confined to the dumps. The ore is a moderately white grade of coarsely crystallized barite, remarkably free from impurities other than the usual discoloration from the red iron oxide. Several lumps of the ore showed cavities filled with nearly perfect quartz-crystals. Drused surfaces of large tabular barite-crystals are abundant. The ore was traced from the surface downward in the openings, observing a general but variable dip toward the southeast. It is reported to be pockety in mode of occurrence, widening and narrowing sharply and frequently, but having a thickness of about 3 ft. where worked in the deep shaft.

Evidence is apparently lacking for regarding the ore as a re-

placement-deposit. It probably represents a filling of an irregular fracture in the crystalline schists, the barium salt of which was probably derived from some mineral or minerals composing the surrounding rocks.

## VI. THE VALLEY (PALEOZOIC) REGION OF SOUTHWEST VIRGINIA.

The Virginia Valley region lies west of the Blue Ridge and comprises a vast thickness of Paleozoic sediments, the principal member of which is the Valley or Shenandoah limestone, separable into several divisions, of Cambro-Ordovician age. Barite occurs in a number of counties in the middle and northern parts of the Valley, but mining of it in the Valley province has been confined largely to Russell, Smyth, and Tazewell counties in southwest Virginia. Wherever commercial deposits of barite have been opened in this province they have been found in association with the Shenandoah limestone or its residual decay. Within recent years, mining-operations have been limited to Tazewell and Russell counties.

### 1. *Mode of Occurrence.*

In southwest Virginia the barite is in association with the Shenandoah limestone or its residual decay. It observes certain minor variations of occurrence from place to place. It fills in part, at least, fractures in the limestone, and in part it replaces the limestone. These occurrences of barite in the limestone are fairly well shown in the southeastern part of Wythe county. Here the mineral associations with barite are limonite, sphalerite, galenite, pyrite, and occasional fluorite, in certain openings named below, from which iron- and zinc-ores have been mined. In the Tazewell-Russell counties area the common associates are limonite and calcite, with some siderite, and occasional fluorite.

In addition to its occurrence in the fresh limestone, the barite is found as small and large nodules irregularly distributed through the red clay resulting from the decay of the limestone. Variation in local occurrence and in mineral association is brought out in the following description of the individual areas.

## 2. *Wythe County Area.*

In the southern part of Wythe county, and near the eastern margin of the Shenandoah limestone, barite occurs in association with the metallic ores in some of the zinc- and iron-mines. No attention has been given to the mining of barite in this locality, nor is it known whether commercial deposits of the mineral exist.

In several of the brown-iron-ore pits at Ivanhoe, barite has been observed in some of the limestone pinnacles as irregular porous or cellular masses intimately associated at times with pyrite, sphalerite, and galenite. These latter minerals, sulphides, were noted in several instances as inclosures in the barite, and the barite replaces in part the limestone. Northeast of Ivanhoe, at the Bertha zinc-mines, which have been operated for several years for iron-ore, barite is found in places as loose nodules imbedded in the red clay derived from the limestone decay.

About 0.5 mile NE. of Bertha, at the Barren Springs iron-ore pits, barite is again found similarly occurring. The mode of occurrence and the associations of the barite in the above localities suggest the introduction of the barium salt along fracture-lines in the limestone and part replacement of the limestone by barite. Moreover, there is every reason for regarding the barite, sulphides, and the little fluorite found as having been brought in and deposited at the same time. Whether the sulphides were carried as soluble sulphides, or as sulphates and deposited as sulphides, there is no convincing evidence.

## 3. *Smyth County Area.*

Barite was extensively mined some years ago near Marion, the county-seat of Smyth county. Mining and shipping of barite in this county were begun about 1877, and the work was continued more or less energetically until about 1885. Some mining on a small scale has since been done from time to time. Barite mining in this county was largely confined to an area about 3 miles west from Marion, with but a small amount of material mined on the east side of the town. Most of the barite mined was prepared by several local mills, the greater part being prepared by the mill at Marion.

The mining of barite was largely confined to the lumps and nodules of the mineral imbedded in the residual red clays derived from the Shenandoah limestone. The barite nodules were often mixed with cherty masses and broken or detached pieces of limestone. The mining did not reach 100 ft. in depth. In some instances mining was extended into the fresh and hard limestone. Gradation from the barite into the limestone was shown, and in such cases much care and labor were necessary to separate the two. The exposures of limestone in some places showed more or less barite mixed with it.

#### 4. The Russell-Tazewell Counties Area.

Extensive deposits of barite are found in Russell and Tazewell counties, these being the largest producers of barite at present in the State. Geographically, the distribution of the barite in these two counties is chiefly along the southern slope of Kent Ridge and its prolongation NE.-SW. along the valley

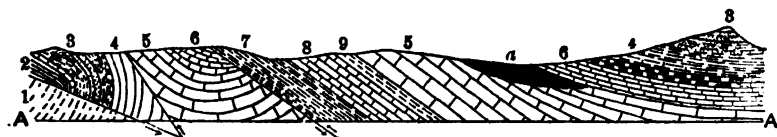


FIG. 6.—STRUCTURE SECTION ALONG LINE A—A OF FIG. 9, SHOWING STRUCTURAL RELATIONS OF THE BARITE AND ROCKS. *a* IS BARITE. Adapted from *Tazewell Folio*, U. S. Geological Survey.

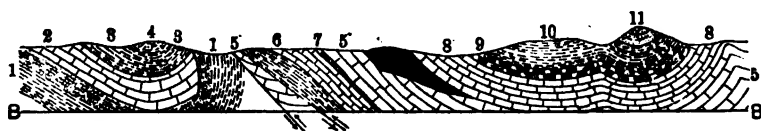


FIG. 7.—STRUCTURE SECTION ALONG LINE B—B OF FIG. 9, SHOWING STRUCTURAL RELATIONS OF THE BARITE AND ROCKS. BLACK IS BARITE. Adapted from *Tazewell Folio*, U. S. Geological Survey.

of Clinch river, extending from near North Tazewell to near Lebanon, a distance of more than 30 miles, partly shown in Fig. 9.

Barite has been mined at numerous points along this NE.-SW. belt, the principal mines being near North Tazewell; 3 miles south of Richlands; 3 miles from Honaker on the Clinch river; and on the southwestern end of the belt near Lebanon.

Throughout this belt the barite is found in the upper portion of the Knox dolomite and its residual decay. Sections, Figs. 6 and 7, show the structural relations of the Knox dolomite and the adjacent rocks on the northwest and southeast, near Sword creek and Richlands, in Tazewell county.

The barite occurs as small and large lumps of irregular shapes assembled in the residual clay of the limestone, and in pocket-form and vein-like bodies filling spaces in the limestone, and in part replacing the limestone. Fig. 8 illustrates one of the principal modes of occurrence of barite in this area. The barite is crystalline, of good white quality, and in most places is quite free from impurities. The mines of the Clinch Valley Barytes Co., near Honaker and Gardner, show a coarsely-crystalline white barite, in platy, more or less radiate masses—

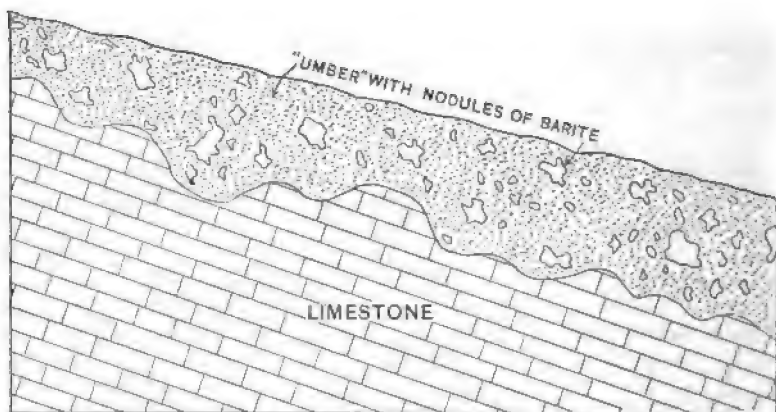
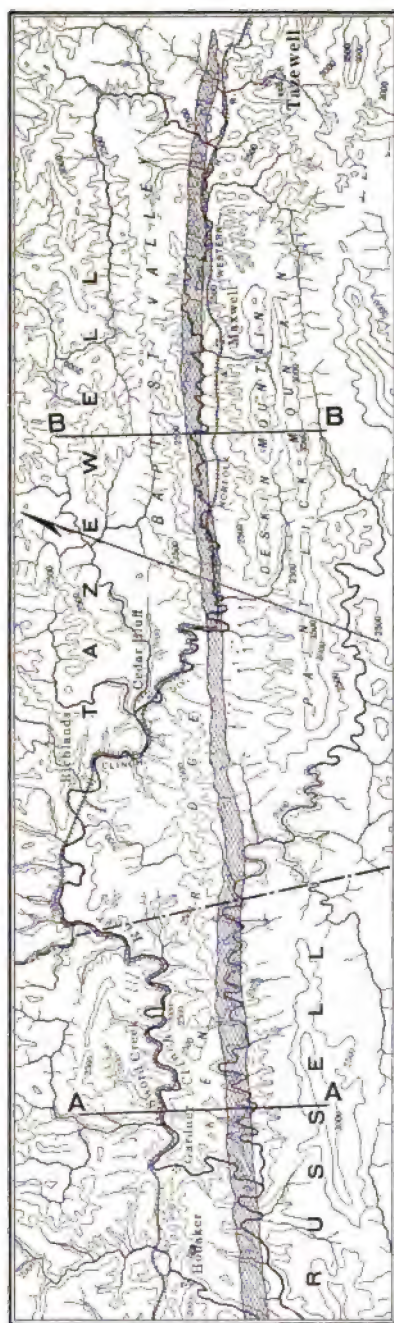


FIG. 8.—PRINCIPAL MODE OF OCCURRENCE OF BARITE IN RUSSELL AND TAZEVELL COUNTIES.

a structure which is strongly emphasized on weathered surfaces of the ore. The commonest impurity at these mines is iron oxide, mostly in the form of limonite. Manganese oxide occurs but sparsely, or not at all. In one of the pits a little violet fluorite and small fragments of green chert were noted in association with the ore.

The greatest depth attained in mining is 103 ft. at the mines of the Pittsburg Baryta & Milling Corporation on the northeast end of the belt. Most of the mining done has been for the lump or nodular ore occurring in the limestone clays, won from shallow open pits and cuts. Some hard-rock mining in the



Contour interval, 500 ft.

Scale, 0.25 in. = 1 mile, approximately.

FIG. 9.—MAP OF A PART OF TAZEWELL AND RUSSELL COUNTIES, SHOWING POSITION OF GREATER PART OF BARITE ZONE. CHECKED AREA THROUGH CENTER OF MAP IS BARITE. Adapted from the Economic Geology Sheet of the *Tazewell Folio*, U. S. Geological Survey.

limestone has been done in places. It is probable that in the future much limestone-ore will be mined, since large bodies of excellent grade material are exposed at several places along the belt, especially on the properties of the Pittsburg Baryta & Milling Corporation.

At the NE. end of the belt an ore-body 4 ft. wide has been mined to a depth of 22 ft. and for a distance of more than 300 ft. The ore has been tested to a depth of more than 100 ft. without indications of its exhaustion. Preparations are being made to mine this ore-body to a greater depth. The barite occurs in vein-like bodies in the limestone, is very white, free from impurities, and makes the best "snow-flake" grade manufactured by the company. On the extreme southwest end of the belt, near Finney, the properties of the same company show ore-bodies in the limestone of the same white and otherwise excellent grade of ore as that described above on the northeast end. Three miles south of Richlands this company has mined more than 6,000 tons of barite from its property. Unlike the ore described above on the two ends of the belt, that south of Richlands is lump ore mined from the red limestone clays.

## VII. GENESIS OF THE BARITE-DEPOSITS.

The work of F. W. Clarke, Sandberger, and others, demonstrates the wide distribution of barium in rocks, usually present only in minute traces, but not infrequently in appreciable quantity. In the absence of necessary chemical work on the Virginia rocks in which the barite-deposits are found, but from the field-character and relations of the deposits, it seems reasonable to assume that the source of the barium was largely if not entirely the rocks in which the deposits are now found. There is no evidence in support of a deep circulation.

The barium of the Valley barite-deposits is believed to have been derived from the Shenandoah limestone, the rock in which the deposits are found. Of that forming the deposits east of the Blue Ridge in Piedmont, Virginia, it is not possible to say whether the barium was derived from the crystalline schists or from the associated limestone-masses, or from both. It is reasonably certain, however, that the source of the barium in the deposit near Thaxton, Bedford county, was the silicate minerals of the granite, probably the feldspar.

The barium was probably liberated and carried in solution as the soluble bicarbonate when, under proper conditions, it was precipitated as the insoluble sulphate. Some recent laboratory experiments made by Dickson with solutions of barium carbonate on selenite crystals and pure anhydrite in the presence of  $\text{CO}_2$ , and on pyrite crystals in the presence of an oxidizing agent,  $\text{H}_2\text{O}_2$ , resulted in each case in the precipitation of barium sulphate. The presence of pyrite in the Virginia rocks may suggest the possibility of its connection as a precipitating-agent in the formation of the barite-deposits, but lack of sufficient data renders it impossible at this time to state the conditions under which the precipitation of the barium sulphate took place and the agents involved.

#### VIII. METHODS OF MINING.

Mining of barite in Virginia is surface-work, with no deep mining in any part of the State. The greatest depth yet reached in any of the mines is 160 ft., in a shaft recently operated at the Hewitt mine, in Campbell county. In the crystal-line area east of the Blue Ridge the ore is won by vertical timbered shafts and drifts which follow the direction of the ore-bodies. The machinery employed is simple, light, and inexpensive. In the limestone belt of southwest Virginia the mining is shallow and largely by open-pit work. Blasting is necessary for breaking down the ore in the fresh limestone.

#### IX. PREPARATION OF THE ORE.

For the removal of impurities from the better grades of merchantable ore, washing, bleaching, and grinding, and occasionally jigging, are the only necessary operations. The common impurities in the best grades of ore include the iron oxide and manganese oxide, limestone, clay, and sand. The ore in the limestone in the Valley region of southwest Virginia is both jigged and washed before bleaching and grinding. The preparation of barite has been described by Higgins.<sup>2</sup>

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<sup>2</sup> Barytes and Its Preparation for the Market, *Engineering News*, vol. liii., p. 196 (1905); Bleaching Barytes, *Engineering and Mining Journal*, vol. lxxix., p. 465 (1905).



### X. BARITE-MILLS.

The barite mined in Virginia is prepared for market at the following plants: The plant at Lynchburg, owned by Nulsen, Klein & Krausse; the plant at Honaker, owned by the Clinch Valley Barytes Company; the plant at Richlands, owned by the Pittsburg Barytes & Milling Corporation; and the plant at Bristol, owned by John T. Williams & Sons.

All except the Lynchburg plant are situated in southwest Virginia. These mills are modern, of large capacity, and fully equipped with machinery.

### XI. CONCLUSIONS.

From the description detailed above of barite occurrence in the Virginia areas the following general facts are deducible:

(1) With two exceptions, the barite-deposits are associated with limestone or its residual decay. These exceptions show the occurrence of the barite in crystalline siliceous rocks more or less remote from limestone masses.

(2) The occurrence of the barite in the limestone is partly as a replacement, and partly as vein-like masses filling fractures; and in the residual clays as loose nodular masses irregularly assembled and of different sizes and shapes. In each of these occurrences the barite is crystalline in texture, and is the result of solution and deposition.

(3) The barite and associated minerals suggest deposition from reasonably-shallow circulations. The barite is believed to have been largely, if not entirely, derived, in most cases, from the rocks in which the concentrations are now found.

## The Presence of Gold and Silver in Deep-Sea Dredgings.

BY LUTHER WAGONER, SAN FRANCISCO, CAL.

(New York Meeting, April, 1907.)

HAVING given in a former paper<sup>1</sup> the results of assays of sea-water, bay-mud, dredgings from San Francisco bay, etc., and believing it might be interesting to extend the work to include some deep-sea dredgings, I procured from the Smithsonian Institution six samples taken by the U. S. steamer *Albatross*, and marked as follows:

No.	Station.	Locality.	Latitude.	Longitude.	Depth in Fathoms.
1.	2103.	Off Delaware bay.	38° 47' 20'' N.,	72° 37' W.,	1,091.
2.	2265 to 2297.	Between Chesapeake bay and Hatteras.	35° 37' N.,	74° to 75° W.,	49 to 70.
3.	2420.	Off Chesapeake bay.	37° 03' 20'' N.,	74° 31' 40'' W.,	104.
4.	2528.	East of Georges bank.	41° 47' N.,	65° 37' 30'' W.,	677.
5.	2572.	SE. of Georges bank.	40° 29' N.,	66° 04' W.,	1,769.
6.	2681	South of Nantucket.	39° 43' N.,	70° 29' W.,	990.

The above samples were assayed by the cyanide-method, described in my former paper (p. 807), about 30 g. of sample being used, and the following results were obtained:

### *Value in Milligrams Per Metric Ton.*

No.	Station.	Gold.	Silver.
1.	2103.	145	1,014
2.	2265 to 2297.	44	304
3.	2420.	15	353
4.	2528.	267	1,963
5.	2572.	125	377
6.	2681.	66	414

No. 4, Station 2528, consisting of red clay and volcanic ash, was re-assayed; 35 g. was roasted at a low heat for one hour and weighed 34.05 g. after roasting; the color was changed to a deep brick-red; and when assayed by the cyanide-method

<sup>1</sup> The Detection and Estimation of Small Quantities of Gold and Silver, *Trans.*, **xxi.**, 798 to 810 (1901).

the material was found to contain 94 mg. of gold and 496 mg. of silver per metric ton, from which it appears that roasting is not beneficial. This sample, and Nos. 3 and 6, were also assayed by fusion with lead upon coal (using 500 mg. of sample), and gave much larger amounts of silver, from which it may be concluded that the cyanide does not extract all of the silver.

The general result of the assays indicates that the bed of the Atlantic, whether coastal or pelagic, carries appreciable amounts of gold and silver, and that the deep-sea bottom is relatively richer in gold than that nearer the shore line.

I desire to thank Mr. L. E. Aubury, State Mineralogist of California, and his staff, for the use of the laboratory of the California State Mining Bureau, and for aid rendered during the investigation.

## **Chronology of Lead-Mining in the United States.\***

BY W. R. INGALLS, NEW YORK, N. Y.

(Toronto Meeting, July, 1907.)

THE following chronology presents the history of lead-mining in the United States in a brief form and is a useful reference in connection with the statistics of production:

1621.

Lead was mined and smelted near Falling Creek, Va., to supply the local demand for bullets and shot. This was the first mining and smelting of lead in what is now the United States.

1682.

In a report made on the minerals of New England, lead-ore is mentioned. (Bishop, I., 470.)

1650.

Supposed beginning of mining by Jesuits in Pima county, Ariz.

1651.

Grant of lead-mine at Middletown, Conn., to Gov. John Winthrop.

1682.

Lead-ore supposed to have been discovered in Wisconsin by Nicholas Perrot. (R. D. Irving, *Mineral Resources of Wisconsin*, *Trana.*, viii., 498.)

1700.

Discovery of lead in Missouri by Penicaut, one of Le Sueur's party. The same expedition discovered lead near the southern boundary of Wisconsin in August of the same year.

1712.

Grant by Louis XIV. of the Crozat patents, with special privileges respecting the discovery and operation of mines in the then territory of Louisiana. Little or no mining was done under this patent until about 1720.

1717.

Transfer of Crozat patents to the Mississippi Co., promoted by John Law, which prepared for active mining.

1719.

First attempt to mine and smelt lead in Missouri, made by Sieur de Lochon, in behalf of the Mississippi Co., near Meramec river. Results unsuccessful.

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\* This paper was prepared for the Carnegie Institution, Washington, D. C., as a part of the industrial history of the United States, and is published here with the permission of Hon. Carroll D. Wright, director of that work.

1720.

Philip Francis Renault, appointed director-general of the mines of the Mississippi Co. in 1719, arrived at Kaskaskia with 200 artisans and miners and 500 slaves, and sent out exploring parties from there, one of which discovered the deposits of Mine la Motte, in Madison county, the mine taking its name from M. La Motte, a mineralogist accompanying Renault, under whom it was operated.

1723.

Grant of Mine La Motte to Renault.

1724-6.

Discovery of lead at Old Mine and Mine Renault, north of Potosi, Washington county, Mo.

1730.

A company of German miners was sent out to the colony of New Netherlands by Baron Horsenclaver. These miners explored the Highlands and made many ventures in mining and smelting.

1731.

Failure of the Mississippi Co. and reversion of its charter to the Crown.

1738-1740.

About this time the Mine La Motte was considered public property, and the people in general were allowed to work at it. It furnished almost all the lead then exported from the Illinois (Moses Austin).

1740.

Operation of lead-mine near Northeast, Dutchess county, N. Y. The mine produced a small quantity of ore, but not profitably. The ore was sent to Bristol, England, and to Amsterdam.

1742.

Return of Renault to France, bringing to a close the first period of mining in Missouri.

1750.

Discovery of the Wythe mines, Virginia, by Col. Chiswell. Worked during the Revolutionary War, and afterwards intermittently up to 1838, and since then rather continuously.

1754.

Lead-ore was known to exist at Southampton, Mass., as early as this year, and lead was mined at Worcester, Mass. (Bishop, I., 493.)

1762.

Cession of Louisiana to Spain.

1763.

Discovery of Mine à Burton, at Potosi, Mo., and immediate inauguration of exploitation. This, together with Old Mine and Mine Renault, both near Potosi, and the Mine La Motte, were the principal mines worked during the next 30 years.

1765.

Development of lead-mine at Southampton, Mass. Work suspended by Revolutionary War and not resumed until 1809. Never became important.

1766.

Capt. John Carver found lead-ore in abundance at Blue Mound, Wis. The Indians knew of it, but did not know how to obtain the metal.

1767.

Governor Clinton, of New York, directed attention to the existence of valuable veins of lead-ore in that colony, and stated that the British Government had leased a mine of argentiferous galena to Frederick Philipse. A large refinery of lead or of iron existed at Sing Sing prior to, or at the beginning of, the Revolution. (Bishop, I, 527, 533.)

1769.

Destruction of settlement at Mine La Motte by Chickasaw Indians and abandonment of the mine, which was not reopened until 1780 or 1782.

1778.

Operation of lead-mine near Birmingham, Blair county, Pa.; resumed in 1795, and again in 1864. Never important.

1788.

The first mining in the Wisconsin-Iowa region was done at Dubuque, Iowa, by Julien Dubuque, who received grant of a lead-mine from the Fox tribe of Indians. Dubuque worked this mine until his death (in 1809).

1789.

Tariff on lead fixed at 1c. per lb.

1795.

Discovery of the Mine à Lanye, about 16 miles SE. of Potosi, Mo.

1799.

Discovery of the Mine à Maneto, on Big river, St. François county, Mo.; also Mine La Platte, about two miles from Big river, near the SE. corner of Washington county.

Arrival in Missouri of Moses Austin from Wytheville, Va.; improvement of smelting methods, erection of shot-tower, and works for manufacture of sheet-lead.

1801.

Discovery of Mine à Joe, later called the Bogy Mine, on Big river, St. François county, Mo.

1803.

Discovery of Mine à Martin near Potosi, and several other deposits in Washington county, Mo.

Louisiana purchased by the United States. Most of the French and Spanish concessions, when they had been continuously occupied, were confirmed by a commission.

1806.

Discovery of New Diggings, near Potosi, Mo., which for a few years produced about 1,000 tons of galena per annum.

Discovery of mines at Hazel Run, about five miles NE. of Bonne Terre, St. François county, Mo., which are said to have yielded 500 tons of lead in the first year.

1807.

Act of Congress reserving all lead-lands in territory of Louisiana and authorizing the Governor to grant three-year leases to discoverers at royalty of 10 per cent. of the product. (*American State Papers*, 2d ed., IV., pp. 526, 555.)

1811.

Discovery of Shibboleth mines, near Cadet, Washington county, Mo., which in the first year are said to have yielded 2,500 tons of ore, equivalent to 1,563 tons of lead.

1812.

Tariff on lead raised from 1c. to 2c. per lb.

1814.

The Fourche à Courtois mines, at Palmer, Washington county, Mo., were discovered.

1816.

Tariff on lead fixed at 1c. per lb.

1820.

Lead-ore worked at Ellenville, N. Y., but with little success. Several veins worked there about 1854 and two Scotch hearths erected.

1821.

Attention attracted by explorers to the Wisconsin lead-region.

1824.

Import duty on lead raised from 1c. to 2c. per lb.

1824.

Discovery of Sandy mines, near Hillborough, Jefferson county, Mo., which soon became large producers.

Joseph Schutz discovered the Valle mines, seven miles north of Bonne Terre, St. François county, Mo.

1825.

Bisch's mine, near the Valle mines, was discovered.

1826.

Development of Eaton mine, near Madison, Carroll county, N. H. Vein leanly mineralized with blende and argentiferous galena.

1828.

Tariff on lead raised from 2c. to 3c. per lb.

1830.

Golconda mine in Franklin county, Mo., discovered.

1832.

Discovery of small veins of lead-ore near Lubec, Me., and beginning of development; results never successful.

Final withdrawal of the Indians from Wisconsin.

1834.

Discovery of Virginia mine, near St. Clair, Franklin county, Mo., extensive developments being immediately undertaken. Smelting begun in 1835.

In consequence of the large number of illegal entries, the miners and smelters of Missouri refused to pay royalties and the Government was unable to collect. (J. D. Whitney, *Metallic Wealth of the United States*, p. 405.)

1835.

Operation of lead-mines at Rossie, N. Y.; continued until 1840.

1836.

Discovery of Washington, known later as Silver Hill, mine in Davidson county, N. C. Worked almost uninterruptedly until 1852. Reopened in 1855.

Erection at Webster, Washington county, Mo., of first Scotch hearth furnace in Missouri. (G. C. Swallow, *Report of Geological Survey of Missouri*, II., 59.)

1837.

Reed and Hoffman erected works for manufacture of white lead at St. Louis. Other works were erected soon afterward at the same place.

Operation of vein of lead-ore near Redbridge, N. Y.

1838.

Value of cerussite ore, "dry bone," first recognized in Missouri, leading to the erection of new furnaces and an increase of product. (James E. Mills, *Geological Report on the Mine la Motte Estate*, p. 47.)

1839.

Discovery of lead-ore at Rosiclare, Hardin county, Ill.

1846.

Operation of lead-mine near Shelburne, Coos county, N. H.

Tariff on lead reduced to 20 per cent. ad valorem.

1847.

Congress decided to sell the National lead-lands in the Mississippi valley.

1848.

The Avon mines, Sta. Genevieve county, Mo., produced eight tons of lead.

Mining of lead-ore begun two miles east of Joplin, Mo., by William Tingle.

1850.

Mining done on small scale near Phoenixville, Chester county, Pa.

Mining begun near Granby, Newton county, Mo., in which vicinity operations were well under way by 1857 and a large output was being made.

The air- or Drummond, furnace was first tried for lead-smelting in Newton county, Mo.

1851.

Mining begun on Center creek, near what was later called Minersville, now Oronogo, near Joplin, Mo.

Erection of first Scotch hearth furnace in southwestern Missouri, located near mouth of Cedar creek, Newton county.

Lead-smelting furnace erected on West Sugar Loaf creek, Ark., this being the first in that State.

1852.

Resumption of mining at Rossie, N. Y.

1853.

Resumption of mining at Ancram, Columbia county, N. Y.

1855.

The Mowry mine, south of Tucson, Ariz., purchased by Major Ewell and others.



1857.

Tariff on lead reduced to 15 per cent. ad valorem.

Establishment of town of Granby, Mo., and erection of furnaces by Peter E. Blow and Ferdinand Kennett.

1858.

Discovery of rich vein of lead-ore at Guymard, N. Y.; operated until 1868 and later.

The Mowry mine passed into the hands of Lieut. Sylvester Mowry, who from this date until 1862 operated it on a considerable scale. This appears to be the first silver-lead mine west of the Rocky mountains to have been operated in an extensive way. The Confederate army is reported to have been supplied with some lead from this source.

1859.

Discovery of mines at Georgetown, Colo.

1861.

Tariff on lead raised to 1c. per lb., and later in the year to 1.5c. per lb.

Mine la Motte furnaces destroyed by United States Government, but soon rebuilt.

1862.

Plant of the Mowry mine, Arizona, destroyed by Federal troops.

1863.

First discoveries of argentiferous lead-ore in Little Cottonwood cañon, Utah.

Discovery of the Jordan mine, Bingham cañon, Utah.

Discovery of silver-lead mines at Castle Dome, Ariz., which, on account of Indian hostilities, were not actively worked until 1869.

1864.

First locations at Eureka, Nev., but no important developments were made until 1869, in which year the great silver-lead deposits were opened.

Organization of St. Joseph Lead Co., which purchased La Grave mines at Bonne Terre, Mo. Active operations begun in 1865.

Tariff on lead raised to 2c. per lb.

1865.

Organization of Granby Mining & Smelting Co. to work the mines at Granby, Mo.

Erection and operation of smelting-works at Argenta, Mont.; commonly credited as the beginning of silver-lead smelting in the United States.

1866.

Establishment of the Selby smelting- and refining-works at San Francisco, Cal.

1867.

Discovery of silver-lead ore in the Magdalena mountains, N. M.

Discovery of rich deposits of silver-ore at White Pine, Nev.; these were the first large bodies of silver-ore found in a limestone formation in the United States, and the information gained from them led directly to the discovery of the silver-lead deposits of Eureka soon afterward.

Smelting begun at Oreana, Nev.

1868.

The Emma mine, Little Cottonwood, Utah, was located in August of this year, but no large shipments were made until July, 1870.

1869.

The junction of the Union Pacific and Central Pacific tracks was made at Promontory, Utah, May 10, 1869. The Utah Central railway was completed to Salt Lake City in December, 1869. The completion of the Pacific railways greatly stimulated prospecting along their lines, making available to market the lead in ores previously discovered in Utah and Nevada.

Development of silver-lead mines at Cerro Gordo, Cal.

Inauguration of diamond-drill prospecting by St. Joseph Lead Co. at Bonne Terre, Mo., and discovery of disseminated ore at depth of 120 ft.

The important silver-lead deposits of Eureka, Nev., began to be productive. The American practice of silver-lead smelting has been developed chiefly from the methods introduced in this district.

1870.

First important developments in the districts of Big and Little Cottonwoods, Bingham cañon, Stockton and Tintic, Utah.

The Miller mine in American Fork cañon was discovered, but was not worked extensively until 1871.

Construction of narrow-gauge railway-system in Colorado begun by Denver & Rio Grande Railway Co.

Discovery of lead-mines at Rosita, Colo.

The mines of Eureka, Nev., become large producers.

Beginning of shipments from the great Emma deposit, Little Cottonwood cañon, Utah. This was the principal source of lead in Utah up to 1875, when the deposit was exhausted.

Invention of the siphon tap for lead blast-furnaces by Albert Arents, and its application at Eureka, Nev.

Erection of lead-smelting works at Omaha, Neb.

Discovery of lead-ore in large quantity at Joplin, Mo., followed by the rapid development of that district.

1871.

The mines of Big and Little Cottonwood, Utah, made large shipments.

Discovery of silver-lead ore in Parley's Park district, now Park City, Utah.

Chicago an important smelting and refining center.

1872.

The Ontario vein, Park City, Utah, was located June 19.

Discovery of silver-ore at Georgetown, N. M.

Refining of lead begun at the Germania works, Salt Lake City, Utah.

E. Daggett installed cast-iron water-jackets at the Winnamuck smelting-works, Utah, these being the first water-jackets in Nevada-Utah smelting practice and the first cast-iron jackets employed anywhere.

Discovery of lead-ore in Cherokee county, Kan.

Tariff on lead reduced to 1.8c. per lb.

1873.

Discovery of silver-lead mines in Wood river district of Idaho.

The United States, by Act of Congress, Feb. 12, discontinued the coinage of silver dollars. This Act did not demonetize silver in words, although it did so in effect. The silver dollar was not named in it. Precisely what the Act did was to authorize the coinage of silver half-dollars, quarter-dollars and dimes below standard weight, and of a new silver coin for Asiatic commerce, of standard

weight, to be called the "trade dollar," and to prohibit these coins from being legal tender for more than five dollars in any one payment. The German Government, by Act of July 9, provided for the retirement of its silver coins and the sale of the bullion. By a Treasury order, Sept. 6, France limited the amount of silver to be accepted by its mint. These actions, which were soon afterward followed by similar ones in other countries, were closely involved with the silver question, and the decline in the value of silver, which began at this time, culminating in the crisis following the closing of the Indian mints to the private coinage of rupees, June 26, 1893, had a powerful effect on the silver-lead industry.

1874.

Early in this year, argentiferous lead-carbonate ore was found on Iron Hill, Leadville, Colo., and the Lime and Rock claims were located.

Discovery of silver-lead ore at Darwin, Inyo county, Cal.

Installation of dust-chambers at several Western lead-smelting works and adoption of methods for further treatment of matte.

1875.

Discovery of Horn Silver mine, Frisco, Utah.

Mining was begun at Webb City, Mo.

Tariff on lead raised to 2c. per lb.

1876.

First shipments from Leadville, Colo.

Mining was begun at Carterville, Mo.

Investigations by Anton Eilers and others determined the correct principles in preparing charges of ore for smelting, a development of great economic importance.

1877.

The Bassick mine, near Silver Cliff, Colo., began to show evidence of value.

First smelting-works erected at Leadville, Colo.

1878.

Discovery of the silver-lead deposits of Sierra Mojada, Coahuila, Mexico.

Great excitement at Leadville, Colo., where many new discoveries were made. The output of ore began to be large.

Mines of Hecla Consolidated Mining Co., at Glendale, Mont., became productive.

Discovery of lead-carbonate ore in the eastern part of Gunnison county, Colo.

Blast-furnaces substituted for reverberatory at works of St. Joseph Lead Co.

The American Pig Lead Association, an alliance of the principal lead-miners and lead-smelters of the United States, was formed to maintain the price of lead at minimum of 4c. per lb. The attempt failed.

Introduction of Lewis & Bartlett process at Lone Elm smelter, Joplin, Mo.; this was the first application of cloth-filtration of fume in the metallurgy of lead.

Desloge mill and furnace, adjacent to works of St. Joseph Lead Co., Bonne Terre, Mo., put in operation.

First location made at Tombstone, Ariz.

1879.

First important discoveries in the Wood river district of Idaho. Ore had been known to exist in this district since 1873, but developments were checked by Indian troubles and not actually begun until 1880. The district became productive in 1881, making the first important output of lead in Idaho.

Discovery of lead-carbonate ore at Rico, Colo.; also at Red Cliff, Colo., and at Kokomo, Colo. Considerable excitement in the Gunnison country, Colo.

Discovery of promising deposits of silver-ore at Aspen, Colo., and in the San Juan region in the southwestern part of the same State.

Lead-mines discovered at Barker, Meagher county, Mont.

1880.

Completion of the Southern Pacific railway through Arizona.

The Denver & Rio Grande railway reached Leadville, Colo.

Discovery of Silver Valley mine, Davidson county, N. C.

Strike of miners at Leadville, Colo.

Discovery of lead-ore at Robinson and Kokomo, Colo.

Excitement in the Gunnison district of Colorado, which did not, however, materialize into developments of great importance.

St. Louis & San Francisco, Missouri Pacific, and Kansas City, Fort Scott & Memphis railways extended into Joplin district, Mo.

1881.

Establishment of smeltery at Socorro, N. M., for treatment of ores of Socorro and Magdalena.

1882.

Discovery of the Viola mine at Nicholia, Idaho.

Red Cliff, Colo., began to make a considerable output.

1883.

Maximum output of Leadville, Colo.

Monarch district, Colo., began to be large producer of lead, output attaining maximum in 1885.

Destruction by fire of mill and mine buildings of St. Joseph Lead Co., at Bonne Terre, Mo.; replaced immediately by large and improved works.

The Viola mine, at Nicholia, Lemhi county, Idaho, began to be productive.

Tariff on lead continued at 2c. per lb.

1884.

Aspen, Colo., began to produce a considerable quantity of lead-ore.

The Neihart district of Montana began to attain prominence.

Opening of extensive bodies of lead-carbonate ore at Cook's Peak, Grant county, N. M.

First discoveries in the Cœur d'Alene district, Idaho.

Destruction by fire of works of Desloge mine, at Bonne Terre, Mo., and purchase of mine by St. Joseph Lead Co.

1886.

Mines at Aurora, Lawrence county, Mo., began to be developed.

Discovery of Wardner district on the South fork of the Cœur d'Alene river, Idaho.

First production of lead-ore in the Cœur d'Alene district, Idaho.

Mexican lead-ore, especially from Sierra Mojada, began to be imported into the United States in important quantity.

1887.

Opening of Doe Run mine, near Farmington, Mo.

Contest between local and valley smelters in the market for Leadville ore, with advantage in favor of latter, owing to railway discriminations.

1888.

Attempted corner in the lead market, leading temporarily to high prices, but resulting finally in the failure of Corwith, the chief speculator.

1890.

Establishment of the silver-lead smelting-industry in Mexico, the rapid development of which greatly reduced the supply of Mexican ore available for reduction by American smelters.

Development of disseminated ore at Flat river, Mo.

Tariff on lead continued at 2c. per lb., and lead in ore made dutiable at rate of 1.5c. per lb.

1890.

Completion of Mississippi River & Bonne Terre railway and removal by St. Joseph Lead Co. of its smelting-furnaces from Bonne Terre to Herculaneum.

Completion of Northern Pacific and Oregon Railway & Navigation Co.'s tracks into the Cœur d'Alene district.

1891.

Discovery of silver-lead ore at Creede, Colo.

Incorporation of the National Lead Co., this concern succeeding the National Lead Trust, organized a few years previously.

1892.

Development of large bodies of silver-lead ore at Cook's Peak, N. M., and heavy shipments from that point.

The Maid of Erin mine, Leadville, Colo., shipped its last lot of lead-carbonate ore in December, exhausting its great deposit and practically marking the end of the production of this class of ore at Leadville.

Strike of miners in the Cœur d'Alene district on account of reduction in wages.

Invention of the Howard skimmer for handling zinc crust, which was one of the most important of the mechanical improvements in the Parkes process of desilverization. First put into practical use at the works of the Pueblo Smelting & Refining Co., Pueblo, Colo. The Howard press was invented a little later.

1893.

The report of the Herschell committee, closing the Indian mints to the private coinage of rupees, was published June 26, causing a decline in the price of silver from 81c. to 62c. per oz., and contributing to the industrial panic which occurred this year, leading among other things to the suspension of operations in many silver-lead producing districts of the United States.

All of the mines in the Cœur d'Alene closed temporarily on account of low prices for lead and silver.

All of the smelters at Leadville suspended operations in the autumn, only two of them subsequently resuming.

Importations of small amounts of lead-ore from British Columbia.

1894.

Second strike of miners in the Cœur d'Alene.

Tariff on pig-lead reduced to 1c. per lb., and on lead-ore to 0.75c. per lb.

Formation of association of the principal smelters of Colorado to limit prices to be paid for ores. The combination went to pieces early in 1895 and sharp competition was again inaugurated.

1896.

First patent secured on the Huntington-Heberlein process, a far-reaching and revolutionary improvement in the metallurgy of lead. The process was developed at Pertusola, Italy, by Thomas Huntington, an American citizen, and Ferdinand Heberlein, a German.

Strike of miners at Leadville, Colo., which practically stopped all production during the last six months of the year.

In August of this year the price for lead fell to the lowest point on record in the United States, 2.60c. per lb., New York, having been accepted for several lots. The average for August was 2.73c., and for the year, 2.98c. The lowest price at St. Louis was 2.43c.

1897.

Tariff on pig-lead raised to 2½c. per lb., and on lead in ore to 1.5c. per lb. (Dingley bill.)

The old works of the St. Louis Smelting & Refining Co. at St. Louis, which had been idle for a long time, were again put in operation to smelt ores for southeastern Missouri and the Joplin district. From this time St. Louis increased rapidly in importance as a center of lead production.

1898.

Organization of Empire State-Idaho Mining & Development Co., the beginning of consolidations in the Cœur d'Alene.

The St. Louis Smelting & Refining Co., a constituent of the National Lead Co., acquired property in the disseminated district of Missouri and began its development, leading to a large production of lead in the course of a few years.

1899.

Organization of the American Smelting & Refining Co., which acquired a large number of the silver-lead smelting- and refining-works of the United States. Several of these were promptly dismantled.

Third general strike of miners in the Cœur d'Alene, dynamiting of the Bunker Hill & Sullivan mill, April 29, proclamation of martial law, and final reopening of the mines on a non-union basis.

Entrance of the Guggenheims, under the name of the Federal Lead Co., into the disseminated district of southeastern Missouri.

Strike of smelter workmen in Colorado early in June hindered operations for many weeks.

Great increase in use of lead for electrical purposes (covering cables, etc.).

1900.

Organization of Guggenheim Exploration Co., which acquired, among other property, the capital stock of the Federal Lead Co. and of the Missouri Smelting Co.

1901.

Absorption by the American Smelting & Refining Co. of the smelting interests of M. Guggenheim's Sons, the latter becoming, however, the dominating factor in the amalgamated company.

The American Smelting & Refining Co. assumed control of the lead market, fixing the price both for producers and consumers, and regulating the output by agreement with the large producers and by adjustment of its smelting-charges in connection with small producers. A very large accumulation in the stock of lead on hand occurred this year, which, however, was successfully disposed of in 1902 and 1903.

## 1902.

Betts's electrolytic lead-refining process installed at Trail, B. C.; the first electrolytic lead-refinery to be put in practical operation.

Strike of miners at Flat river, southeastern Missouri.

Output of Cœur d'Alene district, Idaho, limited by arrangement between the leading producers and the American Smelting & Refining Co.

The American Smelting & Refining Co. put the marketing of its lead on a contract basis, filling orders for prompt shipment only at a premium of 2.5c. per 100 lb., this being done to induce consumers to cover their requirements ahead and carry the stocks that formerly the smelter often had to carry.

Further steps were taken by the American Smelting & Refining Co. to centralize its smelting-operations, the Philadelphia plant, at Pueblo, Colo., being closed, and the famous old smeltery and refinery at Kansas City being abandoned and soon afterwards dismantled.

## 1903.

Consolidation of many of the large mines of the Cœur d'Alene by the Federal Mining & Smelting Co.

Organization of the United Lead Co., which secured control of nearly all the manufacturing plants making sheet-lead, pipe and shot, 21 in number, together with a few white-lead works.

Western Mining Co. organized as a subsidiary company of the Guggenheim Exploration Co., acquiring several of the principal lead-producing mines at Leadville, Colo.

In July there was a strike of the smelter-men at the Grant works of the American Smelting & Refining Co., and the plant was closed by the company and abandoned.

## 1904.

Termination of miners' strike in southeastern Missouri. The labor troubles in this district had been a festering sore for two or three years.

## 1905.

Adoption of the Huntington-Heberlein process by the American Smelting & Refining Co. It had previously been introduced in Italy, Germany, Spain, Great Britain, New South Wales, Tasmania, Mexico and British Columbia.

Redirection of attention to many of the old mining districts, including Cerro Gordo, Cal., and Eureka, Nev. Consolidation of Eureka and Richmond companies.

Purchase of the Selby works, at San Francisco, by the American Smelters Securities Co., a sub-company of the American Smelting & Refining Co.

Organization of the United States Smelting, Refining & Mining Co., taking over several independent works, with plans to enter into competition with the American Smelting & Refining Co.

## 1906.

Reopening of many old silver-lead mining districts, idle for from 10 to 30 years previous, including Eureka, Nev., and Cerro Gordo, Cal.

The United States Smelting, Refining & Mining Co. erected an electrolytic lead-refinery near Chicago, Ill., this being the first works of this kind in the United States.

The Guggenheim interests practically secured control of the National Lead Co., thus bringing the major part of the lead-consuming industry of the United States into direct affiliation with the American Smelting & Refining Co.

## The Electric-Air Drill.

BY WILLIAM L. SAUNDERS, NEW YORK, N. Y.

(Toronto Meeting, July, 1907.)

MANY members of the Institute, who participated in the visit made, during the Bethlehem meeting of February, 1906, to the shops of the Ingersoll-Rand Company, at Phillipsburg, N. J., inspected with interest the new Electric-Air drill, which the company had set up for the purpose of showing it in actual operation to American mining engineers. At the request of the Secretary of the Institute, I promised at that time to prepare a paper for our *Transactions*, describing the construction and advantages of the machine. But such a paper would then necessarily have contained much that was only expected or claimed by the designers and manufacturers of the drill, and not yet incontrovertibly proved by varied and long-continued practice. However moderate such statements might have been, they would have given inevitably to the paper, to some extent at least, the air of a prospectus, rather than of a technical contribution. I therefore decided, with the Secretary's approval, to postpone the writing of the promised paper until it could set forth the results of adequate actual practice, as well as the latest details of construction, etc., based upon practical experience. That period has now arrived. The Electric-Air drill has been exhaustively tested in the field, under varied and arduous conditions and upon the hardest rocks. It is now fairly in the field; its merits and performances are matters of unimpeachable record, and its place among established competitors can be definitely determined.

As a representative of the Ingersoll-Rand Co., as well as a member of the Institute, I may be permitted to add that my company, being largely interested in the manufacture of air-



compressors and machinery driven by compressed air, has no desire to injure its own business by claiming for this new machine that it should immediately supersede all existing applications of pneumatic transmission of power for drilling. On the other hand, if we had not satisfied ourselves that it has proved itself the best for given conditions, the company would not have risked its reputation by introducing it, and I, as a member of the Institute, would not have written this paper.

In former contributions,<sup>1</sup> I have discussed the use of compressed air, and opposed, to some extent, the claims of the advocates of electrical power-transmission in mining. I need not now retract any opinion thus declared. Many features of electrical transmission are undoubtedly convenient and economical; but the direct application of the electric current in rock-drilling has long been a baffling problem; of which, in my judgment, the machine here described has furnished the first, and thus far the only, satisfactory solution, by combining the acknowledged advantages of air-driven percussion with the acknowledged advantages of electric power-transmission, while avoiding the acknowledged disadvantages of both systems.

This drill is correctly designated; it is not an electric drill, but more completely an air-drill than any other in existence, because it can be driven by air only and not, like other air-drills, by steam also. Yet, while it is thus distinctly air-operated, the power-transmission is electric, and the sole connection of the drill with the power-house is made by the electric wire, air-compressors and pipe-lines being entirely superseded.

Fig. 1 gives a general idea of the apparatus. It shows a rock-drill, resembling, at first glance, the familiar air- or steam-driven drill, mounted in the usual way, and doing the same kind of work. Very near the drill, and connected to it by two short lengths of hose, is a small air-compressor, or, more properly, a pulsator, mounted upon a little truck. This constitutes the entire apparatus of a single drill. Each drill is accompanied by its individual pulsator, and each pulsator is connected to the line of wire from the power-house.

The usual drill-shell is employed, and may be mounted upon tripod, bar or column, according to the work. The drill-

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<sup>1</sup> *Trans.*, xxxiv., 918, 954.

cylinder, fitted to slide in the shell, is moved forward or backward by the feed-screw. The cylinder is as simple as can be



FIG. 1.—THE ELECTRIC-AIR DRILL AND PULSATOR.

imagined; a straight bore, having at each end a large opening, and a boss to which the hose is attached. The piston also is

plain, much shortened in the body, with a large piston-rod, which has a long bearing in a sleeve-elongation of the cylinder.

Upon the truck is mounted an electric motor, geared to a horizontal shaft, with cranks on each end, which drive two single-acting trunk-pistons making alternate strokes in vertical air-cylinders. One of these air-cylinders is connected by the hose to one end of the drill-cylinder and the other end of the drill-cylinder is connected by the other hose to the other air-cylinder. The air, therefore, in either air-cylinder, in its hose and in the end of the drill-cylinder to which it is connected, remains there constantly, playing back and forth through the hose according to the movements of the parts, being never discharged, and only replenished from time to time to make up for leakage. The propriety of calling the apparatus a pulsator instead of a compressor is evident.

The essential details of the cycle of operation will be easily understood. We may assume, to begin with, that the entire system is filled with air at a pressure of 30 or 35 lb. This pressure being alike upon both sides of the drill-piston, it will have no tendency to move in either direction. If, now, the motor, instead of being at rest, is assumed to be in motion, one pulsator-piston will be rising in its cylinder and the other piston will be descending in its cylinder; and, as a consequence, the pressure upon one side of the drill-piston will be increased and the pressure upon the other side will be proportionately reduced, this difference of pressure causing the drill-piston to move and make its stroke. Just before the end of this stroke, the movement of the pulsator-pistons is reversed, and the preponderance of pressure is transferred to the other side of the piston, causing a stroke in the other direction—and so on continuously. The drill thus makes a double stroke, or at least receives a double impulse, for each revolution of the pulsator crank-shaft.

Having thus sketched the general principle of operation, I will proceed to discuss some of the details. The drill-cylinder, shown in Fig. 2, while generally similar to that of the air- or steam-drill, is in many respects quite different; and especially is it remarkable for its simplicity. The usual operating-valve-chest; the valve and the complicated means for operating it; the main air-ports and the intricate little passages in and con-

nected with the chest—are all absent, and nothing takes their place. The cylinder-heads are both solid and both fastened securely in place. The split front-head, the yielding fastenings for both heads, the buffers, the springs, the side-rods, etc., of other drills, have all been banished. The cylinder is absolutely plain, with direct openings into the interior, and a boss at each end to which the hose is attached.

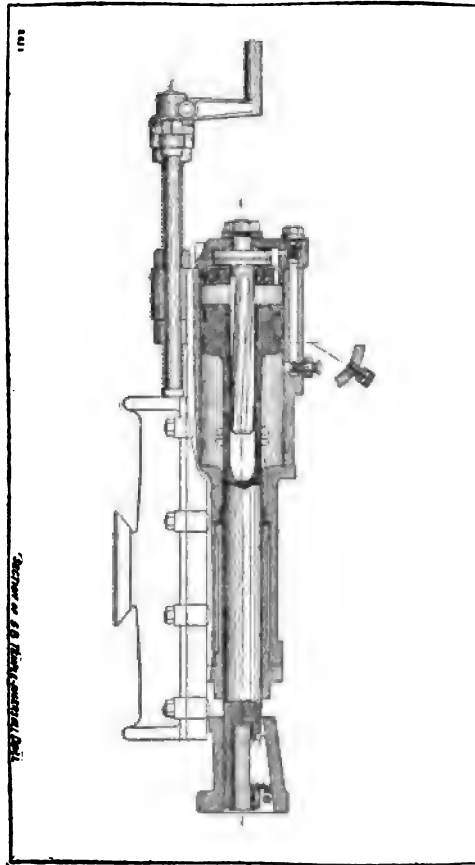


FIG. 2.—SECTION OF DRILL.

The piston also has been simplified. The device for securing rotation is necessarily retained; but the enlargement at the end of the piston-rod, which constituted the chuck and necessitated the split front-head, has been discarded. The piston-rod is much enlarged throughout, and a simple but effective self-tightening chuck is slipped upon the end of it.

The compressor- or pulsator-cylinders are likewise simple. There are no valves for either inlet or discharge, and there is neither jacketing nor the slightest need of it. The heating of the air by the compression-stroke is compensated by the cooling which attends the re-expansion of the same air, so that it does not become increasingly hot and heat the parts of the machine with which it comes in contact.

While this apparatus, as a whole, may appear complicated at first glance, it is really a great advance in simplification. The parts which it eliminates are exactly those which have always been most troublesome and expensive to maintain, and both the drill and the compressor or pulsator are the simplest ever built.

There are some minor details of this apparatus, with which it is not necessary to burden this paper, and which would involve tedious explanations not easily understood without elaborate drawings or models. In the foregoing description of the principle of operation I assumed a mean air-pressure of about 30 lb. in the apparatus. It may be asked, how this pressure is secured and maintained. When the pulsator is in operation, the air-pressure in the cylinders alternately rises above and falls considerably below the mean. At a certain point, indeed, it is below that of the atmosphere; and at this point a little valve is provided, which admits more or less air, until a sufficiency has been provided. At the beginning of operation the influx of air is rapid, so that no time is lost in getting sufficient pressure to begin with. The admission of air and also the apportionment of relative volumes thereof to the two ends of the drill-cylinder are easily adjusted by the operator.

The Electric-Air drill is not troubled by the freezing-up or choking of the exhaust, because there is no exhaust. Moreover, the air does not accumulate moisture, and the temperature does not fall to the freezing-point. Again, air becomes and remains a constant vehicle for the conveyance and distribution of the lubricant. A certain amount of oil being contributed to the system at regular intervals, it would be more difficult to prevent than to insure its reaching every working-part.

The length of hose employed seems to be limited to about 8 ft. on each side. The hose may be attached to either side of the drill, but each always to its own end of the cylinder. This

length of hose gives all necessary liberty for the location of the pulsator-truck near the drill. The truck (of steel, with flanged wheels) is usually made for the standard 18-in. mine-track, but may be made for any other gauge. Special care in leveling is not necessary, since the pulsator will work at any angle at which the truck can stand.

Either a direct- or an alternating-current motor may be employed, the latter being preferred because it is a smaller, lighter, mechanically simpler, hardier machine, and more nearly "fool-proof." Four different speeds may be obtained with the direct-current, and two with the alternating-current motor—in the latter case, full speed for steady running and a considerably lower speed for starting a hole or working through bad ground, with immediate transition from the one speed to the other, as required. The controller is on the top of the motor and the operator at the drill can start, speed or stop the motor by simply pulling a cord, this being the only connection. The electrical connection ends at the motor; both the hose and the cord insulate the drill; and the operator is never exposed to the current.

The 5-C electric-air drill may be regarded as the full equivalent of the 3.25-in. standard air-drill of any make; of its comparative efficiency something will be said later. The power-requirement for this drill is from 18 to 20 amperes at 220 volts, or from 9 to 10 amperes at 440 volts—the electrical equivalent of about 5 h.p. The system being a closed circuit, this is independent of conditions of altitude, which make so much difference with the work of the air-compressor which supplies the ordinary air-drill.

The 4-C electric-air drill uses a 3 h.p. motor, and is a much lighter drill throughout, equivalent to a 2.75-in. standard air-drill. Table I. gives particulars of size, weight, etc., of both of these drills:

TABLE I.—*Dimensions, Weights, Etc., of Temple-Ingersoll Electric-Air Drills.*

	5-C.	4-C.
Diameter of drill-cylinder, . . . . .	5½ in.	4.75 in.
Length of stroke, . . . . .	8 in.	7 in.
Length of drill—end of crank to end of piston, . . . . .	45 in.	42 in.
Depth of hole drilled without change of bit, . . . . .	24 in.	20 in.
Depth of vertical holes machine will drill easily, . . . . .	16 ft.	8 ft.
Diameter of holes drilled, . . . . . from 1.75 to 2.75		1 to 1.5 in.
Strokes per minute, . . . . .	425	460
Horse power (at motor), . . . . .	5	3

*Weights.*

	Lb.	Lb.
Drill (unmounted, with wrenches and fittings), . . . . .	300	192
Pulsator complete with direct-current motor, mounted on truck, . . . . .	883	585
Pulsator alone, . . . . .	271	160
Truck, . . . . .	102	100
Motor, . . . . .	400	275
Motor without armature, . . . . .	330	216
Armature alone, . . . . .	82	59
Controller, switch and rheostat, . . . . .	72	50
Entire equipment ready for shipment, including drill, pulsator, direct-current motor, fittings, wrenches and extra parts, but no mountings, steels or blacksmith tools, . . . . .	1,680	902
Pulsator complete with 30- or 60-cycle alternating-current motor mounted on truck, . . . . .	630	360
Pulsator alone, . . . . .	271	160
Truck, . . . . .	102	100
Motor, . . . . .	202	137
Motor alone, . . . . .	46	34
Controller-switch with base, . . . . .	45	45
Truck cross-bars for motor, . . . . .	15	15
Entire equipment ready for shipment, including drill, pulsator, 30- or 60-cycle alternating-current motor, fittings, wrenches and extra parts, but no mountings, steels or blacksmith tools, . . . . .	1,080	680
Tripod with weights, . . . . .	540	430

NOTE.—Weight of column and shaft-bar mountings will vary with their length and diameter.

The dimensions and weights of the "Baby" or 3-C Electric-Air drill cannot as yet be put on permanent record. This drill takes the place and does the work of the "Baby" air-drill.

The Electric-Air drill strikes a blow, normally so much harder than that of the air-drill of the same capacity, that it has been found advisable in many cases in "dressing" the steel bits to make them blunter or thicker, in order to avoid breakage. The practical force of the drill had not been computed beforehand, but was demonstrated in extensive practice and experiment, and the clear and sufficient explanation came later.

The drill-piston, when running at full speed, and making a stroke for each rotation of the pulsator crank-shaft, does not strike either head. The hole by which the air enters the cylinder from the hose is located, not at the extreme end, or close to the head, of the cylinder, but a certain distance away, so that when the piston approaches the head a portion of inclosed air acts as a cushion, which first checks the piston and then

shoots it back. The piston thus starts upon its working-stroke impelled by a certain amount of force which, we may say, has been saved over from the preceding stroke to be utilized for this. The piston after being thus started is driven forward by an air-pressure which increases as it advances, the pulsator-piston being in the attitude of chasing and gaining upon the drill-piston for a considerable portion of the stroke, while in the case of the ordinary drill-piston, driven by a constant flow of air from which it runs away, the pressure must constantly diminish as the piston-speed is accelerated. In the same way by the action of the other pulsator-piston the opposing pressure upon the advancing side of the drill-piston is a diminishing pressure instead of the constant atmospheric resistance, and these combined cause a greater unbalanced difference of pressures upon the opposite sides of the drill, a more rapid acceleration of the piston-movement, and a consequent higher velocity and force at the moment of impact of the steel upon the rock.

Perhaps the most gratifying, and also surprising, revelation of all in connection with the Electric-Air drill is the now indisputable fact that it takes only from one-third to one-fourth of the power, at the power-house, to drive it to do the same work. This is accounted for by the fact that the same air is used over and over, and that all of its elastic force is availed of in both directions instead of exhausting the charge for each stroke at full pressure. There are also no large clearance-spaces to fill anew at each stroke, as these spaces are never emptied.

A valuable feature of the Electric-Air drill, is the ability to yank the bit free if stuck in a hole and immediately continue its work. When the bit of the ordinary air- or steam-drill sticks in the hole, the drill stops and the drill-runner must free the bit as best he can. Ordinarily the feed is run up and down, the drill is hammered and things are coaxed in various ways until the bit is free. When the bit of the Electric-Air drill sticks, the motor and the pulsator-pistons do not stop. If the drill-piston is making, say, 400 strokes a minute, as soon as the bit becomes stuck the piston will receive per minute 400 alternate thrusts and pulls with full force, and nothing could be more effective for freeing the bit than these alternate thrusts and pulls. Often when the bit sticks and before the runner



can get ready to do anything about it, the drill frees itself and is running again as if nothing had happened.

The coming of the Electric-Air drill suggests many possibilities and ominously means much to established interests. It necessarily suggests a revolution in methods and sometimes perhaps a superseding of the old plants throughout. In the working of the new drill the old central air-compressor plants are absolutely worthless, but it is not easy to imagine any general abandonment of them. After all, the result may probably be that the new drill will not to any great extent drive out the old, but will make a new field of employment for itself, and in that way lead as usual to a considerable enlargement of the already extensive business which is behind it. As has been shown, the Electric-Air drill is far from an electric drill, but the ordinary electric current, now nearly everywhere available, can be used for operating it.

In planning new installations the Electric-Air drill is to be most seriously considered. The relative final cost of operating this or any other drill, is, after all, the decisive question, due recognition, of course, being given to the peculiarities of each drill, favorable or otherwise, which are not computable, but which still have weight in determining the selection, "other things being equal."

When the Electric-Air drill is operated without its own generating-plant, the current being taken from a large power-company, some very low figures are already on record. At Idaho Springs, Colo., a mine-shaft was put down 67 ft. in 24 shifts and the total power-cost was \$24 for the entire work.

In making rock-excavations for building-purposes in New York City and elsewhere, steam-drills, having a temporary boiler-installation, are frequently used. The Electric-Air drill not only avoids the expense of the boiler-equipment but will do the work at a much lower cost, the current being supplied by one of the big electric power-companies.

## Secrecy in the Arts.

BY JAMES DOUGLAS, LL.D., NEW YORK, N. Y.

(Toronto Meeting, July, 1907.)

THOUGH liberality is not supposed to be a prominent trait of the Scottish character, Canada owes to a Scotchman, Sir Wm. Macdonald, more than to any other of its people, not only wise ideas, but pecuniary help towards extending education: and another Scotchman, in New York, has sumptuously housed under one roof three branches of the engineering fraternity, of which we are one.

Having thus created us members of the same family—for the metaphorical meaning of house and kinship is identical—Mr. Carnegie expresses more emphatically than even he could in words, that, by affording facilities for closest intercourse, he invites the mechanical, electrical and mining engineers to participate in the freest interchange of idea and experience, and to correlate and combine the results of their studies and activities; and, being members of the same household, to banish reserve and secrecy.

And now we, the members of the American Institute of Mining Engineers, meet as though we were at home in a neighboring country. For whether we meet in Canada, in England, or elsewhere, the Institute is always received as though no political or geographical divisions separated its members from those of congenial associations in the land of its host. In truth, the title which we have assumed claims for the sphere of our activities the whole American continent, regardless of such trifling details as boundary-lines. The fact that we meet to communicate each other's experience, to discuss our difficulties, and to seek each other's aid in solving the intricate problems that so often present themselves in the course of our professional life, is an acknowledgment of our individual helplessness; and therefore an argument for united effort. But no effort can be of any value if there is an underlying suspicion

of reserve and lack of candor in our treatment of the technical questions which it is our province at these meetings to discuss.

Yet there are limits to the extent to which we may go as officials of public companies. We know that even as professional men it is not always easy to reconcile principles with practice, and on this subject of sincerity and transparent diffusion of our experience there is some slight difference of opinion and difficulty of application. Few of us are as favorably situated as the college professors, whose first duty is to unbosom themselves to their students of all they know, and perhaps of a little which they only suppose they know. The most of us are paid officials of corporations whose *raison d'être* is to make money, and whose executive officers sometimes, not without some reason, consider their trade secrets as part of their capital. Some companies confide these secrets to the honor of their technical workers under as strict rules as those imposed on their cashier in the distribution of their money. Unless, therefore, our employers permit, we as employees are under pledge of secrecy. Many large manufacturing, mining and metallurgical concerns put no restriction upon the freedom of their technical staff, but some of our largest certainly impose on their employees absolute silence as to all that transpires within their laboratories or workshops.

If the question were left to us alone, it would be easy of solution. Our reliance on one another, as workmen in such distinct branches of engineering as civil, mechanical, electrical, and mining, is so close that we must co-operate in every large enterprise we undertake. We cannot succeed singly, for few of us claim to be so encyclopædic in our knowledge or universal in our experience as to make it safe to rely on our own acquaintance with the practical details of every one of these important departments. We therefore seek each other's assistance, and consequently share in each other's secrets; for every man's special knowledge is to the other man, who is more ignorant or inexperienced, a secret, or a "mystery," as old tradesmen and professional men used to call it.

Every industrial advance brings us closer together and makes it more impossible to act independently. Till very recently the civil engineer surveyed and located the line of railroad; the metallurgist made the rails and the iron and steel for the loco-

motives; the mechanical engineer designed the equipment, and what was left for the electrician to do was to string the telegraph wires. Now all this is changed. The electrical engineer is, in importance, springing into the first rank; and he requires such special acquaintance with the mysterious forces, whose distribution and useful energy he handles with so much audacity, and yet safety, that few of us are particularly anxious to meddle with his operations.

Or, to take a mining instance, in reaching a decision as to the adoption in underground or overground haulage of electricity or compressed air, even in metalliferous mines, the verdict must depend on so many delicate and purely technical considerations that few superintendents or general managers would consider themselves sufficiently informed to commit themselves until their mechanical and electrical advisers had marshaled all the facts and arguments for and against each system. I need not cite other instances in which co-operation is demanded in the carrying-out of almost every modern enterprise, or in the equipment of the complicated mechanisms which have replaced the simpler contrivances of our forefathers. The modern steamship exceeds Columbus's caravels in size and complexity of construction as much as does a limited train an old stage-coach. And in proportion to the multitude of their parts and the tremendous energy of the forces which must be called into play to move them, is the diversity of knowledge, talent and skill required to design, construct and operate them. As I have said, therefore, if it depended upon us alone, there would be no difference of opinion as to the necessity of perfect open-mindedness, and as little backwardness in applying this principle to practice.

I think, moreover, that many of us are also convinced that open-mindedness to the suggestions of others is a useful quality to carry into our work, even after we and our scientific staff, in our joint wisdom, have co-operated in formulating and laying out our plans. Every draftsman in our offices, every master mechanic in our shops, every foreman in our mines, is an expert in his particular line, and may be supposed to be familiar with minutiae which have escaped our observation, or, to put it frankly, may know more than we do ourselves on some of the innumerable details which make up the sum total of the

questions on which we have ultimately to pass. The suggestions coming from such subordinate sources may not always be worthy of acceptance; but, on the other hand, it is never wise on our part to turn a deaf ear or a disdainful shoulder to them. In our own small way and work, we feel sometimes almost ashamed to accept credit accorded to us for ingenuity and foresight in devising either mechanical or industrial novelties, or in organizing enterprises, when we recall the hints from others which have suggested thoughts to ourselves. For though undoubtedly, especially in the most imposing cases, the one inspiring mind has conceived the idea, either of the invention or of the enterprise, only by the co-operation of a number of subordinate agents, who often belong to the multitude of the unknown and forgotten, could the idea have been worked out to the glory and the profit of the inventor or promoter. It is always difficult to decide how much of the result should be passed to the credit of the conspicuous man and how much to that of the hard-working, plodding, unimaginative grubber among details, or to the brilliant, erratic, and, because erratic, unsuccessful fellows who do so much of the world's work, and yet get so little of the praise or the gold. But this is certain, that in our own work, whether it be conspicuous or not, we shall always benefit by inviting suggestions from the humblest of our co-operators, encouraging them to think independently, and fearlessly to express their thoughts. That this is already one of the prominent qualities of American industry is manifest from the large number of patents which are taken out by inconspicuous laborers in the fields of engineering, especially of mechanics.

I recently went, one Friday morning, into our purchasing department and found every desk empty, and all the clerks assembled in the manager's room. He had found it conducive to the most efficient conduct of his office to assemble all his staff once a week for free discussion as to the most economical distribution of work. The result was that instead of late hours and overtime the necessary day's work was obtained very easily within office hours; for suggestions from the men actually engaged were found to be worth more than those from the men merely superintending. The youngest were not snubbed,

if they ventured to make a remark; and thus the spirit of pride and co-operation pervaded the whole group.

We have all heard how Mr. Carnegie is said to have stimulated the rivalry of his superintendents and heads of departments by getting them to meet at intervals over an excellent lunch, where around the table all jealousy vanished, and little technical secrets, which are liable to exist even among friends, were revealed. But good cheer is not, or should not be, necessary to make the great brotherhood of technical workers unfold their sympathy and unbosom their secrets to one another.

But we return to our main subject. How far and how completely should even corporations and industrial concerns permit and encourage the interchange of information? I am inclined to think that few limits should be set; for every limitation means the concealment of some fact or some principle which only if revealed can be developed to its full significance and utility. As a rule this can be best done by the action of many minds and many hands. Till developed it does not yield its full advantage to even the original discoverer, for he alone, unaided, in the solitude of his laboratory or behind the bars of his factory, without the practical assistance of his fellow-workers, rarely brings his original germinal idea into efficient, practical utility.

Were we free to appeal to purely altruistic motives, it would therefore be superfluous to argue in favor of complete knowledge- and experience-sharing, but profit-sharing is after all the impelling motive of industrial advance to-day, as it has been in all ages, and to reconcile the admitted evils of secrecy with the admitted advantages of publicity, the patent laws have been framed. They have always given the patentee the right to use either in his person or through his agent his invention or discovery for a limited number of years, provided he describes it so fully that it can be practiced by one skilled in the art. The publicity and knowledge conveyed by the specification stimulates the inventive faculties of others, and patented and unpatented improvements, along the line of the original invention, demonstrate both the value of publicity and the cupidity of men, even of the technico-scientific class. Among the great inventors of our day was Sir Henry Bessemer. Before the

Royal Commission, appointed to suggest revision of the British patent laws, he gave evidence, some of which he has embodied, with very suggestive comments, in his autobiography.<sup>1</sup> Before he became famous he devised machinery for making bronze powder, and manufactured the powder in secret. Of this he says :

"While referring to patents for inventions, I cannot refrain from pointing to this particular invention of bronze powder as an example that may advantageously be borne in mind by those short-sighted persons who object to grants of letters-patent. There can be no doubt of the fact that the security offered by the patent law to persons who expend large sums of money and valuable time in pursuing novel inventions, results in many new and important improvements in our manufactures, which otherwise it would be sheer madness for men to waste their energy and their money in attempting. But in this particular case the conditions were most unfavourable for patenting, owing to the fact that the article produced was only a powder, and could not be identified as having been made by any particular form of mechanism. Therefore it could not be adequately protected by patent; moreover, by my machinery, the cost of production, if only paid for at the ordinary rates of wages, did not exceed one-thirtieth of the selling price of the article. This fact alone offered an irresistible temptation to others to evade the inventor's claims, and so rendered the patent law a most inadequate protection. On the other hand, the great value of a small bulk of the material made it possible to carry on the manufacture in secret, and this method of manufacture was rendered the more feasible by making each different class of machine self-acting, and thereby dispensing entirely with a host of skilled manipulators. It may therefore be fairly considered, so far as this particular article was concerned, that there were, in effect, no patent laws in existence.

"Now let us see what the public has had to pay for not being able to give this security to the inventor. To illustrate this point, I may repeat the simple fact that the first order for bronze powder obtained by my traveller was for two pounds of pale-gold, at eighty shillings per pound net, for the Coalbrookdale Iron Company. I may further state that, in consequence of the necessity for strict secrecy, I had made arrangements with three young men (my wife's brothers), to whom salaries were paid far beyond the cost of mere manual labour (of which, indeed, but little was required). My friend Mr. Young desired to occupy the position of sleeping partner only, and not be troubled with any details of the manufacture; so I entered into a contract with him to pay all salaries, find all raw materials, pay rent, engine power, and bring the whole produce of the manufactory into stock, in one-ounce packages, ready for delivery, at a cost, for all qualities, of five shillings and sixpence per pound; after which he and I shared equally all profits of the sale. It is rather a curious coincidence that the one-ounce bottles of gold paint were labelled five shillings and sixpence each, off which the retailer was allowed a liberal discount.

"Had the invention been patented, it would have become public property in fourteen years from the date of the patent, after which period the public would have been able to buy bronze powder at its present market price, viz., from two

<sup>1</sup> *Sir Henry Bessemer, F.R.S. : An Autobiography*, pp. 82 to 85. London: Offices of Engineering (1905).

shillings and threepence to two shillings and ninepence per pound. But this important secret was kept for about thirty-five years, and the public had to pay excessively high prices for twenty-one years longer than they would have done had the invention become public property in fourteen years, as it would have been if patented. Even this does not represent all the disadvantage resulting from secret manufactures. While every detail of production was a profound secret, there were no improvements made by the outside public in any one of the machines employed during the whole thirty-five years; whereas during the fourteen years, if the invention had been patented and published, there would, in all probability, have been many improved machines invented, and many novel features applied to totally different manufactures.

"I have lingered long over this subject of bronze powder, because it is one which has had great influence on my career; it was taken up at a period when my energy and my endurance, and my faith in my own powers, were at their highest; and as I look on all the incidents surrounding it, through the lapse of time and the many changes of the fifty years since it was undertaken, I wonder how I had the courage to attack a subject so complicated and so difficult, and one on which there were no data to assist me. There were not even the details of former failures to hold up the finger of warning, or point out a possible path to pursue, for no one had yet ventured to try and replace the delicate manipulation which experts had made their own, both in Japan and China, where texts and prayers printed with bronze were offered up at the shrine of Confucius two thousand years before I had ever seen a particle of bronze powder."

He concludes this first reference to his powder in the following paragraph:

"In closing these details of the bronze powder manufacture, I may say that, later on, the handsome royalties paid by my steel licencees rendered the bronze powder business no longer necessary to me as a source of income; and I had then the extreme satisfaction of presenting the works to my brother-in-law, Richard Allen, who had, with so much caution, successfully kept, for more than thirty years, a secret for which, he perfectly well knew, some thousands of pounds would have been given him at any moment."

But he returns to the subject of patents when discussing another invention of his, that for making optical and plate glass, the value of which, for some reason or other, the trade has never appreciated. He says (pp. 117, 118):

"There is one point in connection with patented inventions upon which I have always felt strongly. I have maintained that the public derive a great advantage by useful inventions being patented, because the invention so secured is valuable property, and the owner is necessarily desirous of turning that property to the greatest advantage; he either himself manufactures the patented article, or he grants licences to others to do so. In either case the public reap the advantage of being able to purchase a better or cheaper article than was before known to them, due to the inventor's perseverance in forcing his property upon the market. But if a novel article or manufacture is simply proposed by a writer, and published in the technical press or in newspapers, as a rule (almost without a single excep-



tion) no manufacturer will go to the trouble and expense of trying to work out the proposed invention. He says to himself: 'I shall not risk the expense necessary to develop this new idea, for it may entirely fail; or even if I succeed, its development will cost me much more than it will cost other manufacturers, who will immediately avail themselves of it if I succeed; no, let some one else try it;' and so the invention is lost to the world in consequence of having been given away. This loss to the public is equally the case with patents that are not taken up; and one of the simplest and most effective inventions which I have ever made may be here cited as an example, as it formed part of the novel system of plate glass manufacture just referred to."

After describing his plate-glass invention and its public neglect, he says (p. 122):

"From what I have said I think I have shown that, however self-evident an invention may be, or however advantageous it might be to a manufacturer, if it is public property he will not touch it."

Sir Henry was doubtless correct in asserting that under the impulse of self-interest inventions are pushed by the inventor more vigorously than if he had merely the scientific credit due and given to investigators to spur him on. But he really gives us an argument against patents when he describes the apathy of the public to his glass patents. His steel patents he worked out himself and brought to perfection after years of heavy expense and labor, and by adopting certain modifications to fit special cases. His plate-glass patents he never himself applied, but they would probably have been loaded down with royalties which the trade did not care to pay while taking the risk of applying them to practice. As to his bronze powder, he would probably have made far more out of it had he reduced the exorbitant prices and increased the demand, even while manufacturing it behind closed doors.

It is, however, foreign to my purpose to discuss the patent laws, except casually as they bear upon the subject of secrecy in the arts. Sir Henry's generalizations are substantially correct, but they are too sweeping; for there have been great inventions which the public has not been backward in using, though they were freely given to the world. One's thoughts pass with pleasure from the contemplation of the money-making inventors and investigators to such prophets and apostles of science as Sir Michael Faraday. Sir Michael's profound and original investigations into electricity and magnetism gave the world the dynamo. Though he did not work out the mechani-

cal details of a practical generator, he undoubtedly invented appliances which might have been used for making a strong basis-claim for a patent. But nothing could have been more repulsive to his spirit or foreign to his high aim in life than gauging his time and talents by a mere money standard. He lived contentedly on the small salary he received from the Royal Institution, preparing his lectures to children with as much care as he bestowed on those delivered before the Institution which made him famous; and turning his great learning and power of investigation to the nation's good in return for very scanty remuneration, for he deliberately decided to devote his life to scientific research for truth's sake, rather than to use his vast attainments in the service of Mammon. At the commencement of his career, Faraday added to his salary from the Royal Institution by what he called commercial work. At first, his average earnings from this source were £240 per year. By 1831 they reached £1,090. By 1838 they had shrunk to nothing; for in the meantime his great discovery of magneto-electricity was made, and his thoughts were so intently directed to his experimental work that no time could be spared for money-making.

Faraday's mind was too absorbed in wonderment and almost religious fervor, as the secrets of nature revealed themselves, for sordidness in any form to find lodgment. He wasted his energy neither in money-making nor in captiously defending his discoveries and great conceptions from supposed infringement by other scholars. He never forgot, despite his brilliant original work, that generally the great investigators only lay the keystone in the arch which many less gifted workers have been erecting stone by stone. He did not consider it any detracting from his honor that he was permitted only to crown the structure which others had helped to build from the foundation up. They are the greatest among the great who appreciate this limitation and recognize what they owe to others. Faraday knew that his discoveries gave him but imperfect glimpses of some of the laws and phenomena of nature, which we, through our ignorance and prejudice, are slow in understanding, but which would soon cease to be secrets if we could only disabuse our minds of false conceptions, see facts as facts instead of as arguments for our theories, and then work together with single-heartedness.

Faraday felt also, as every true disciple of science should feel, that when we penetrate to the discovery of even the least important of the facts of nature, we are unveiling one of God's gifts to humanity. If that be so, we may well ask ourselves, what right have we to draw the curtain over it and conceal it again from God's children in order that we may make money out of it? Looked at from this point of view, may we not question the right to buy men's thoughts; and when through their thoughts we have unraveled some of nature's secrets, and learnt something to our profit, use our power and another's necessities to impose secrecy? Are we not enslaving a human mind, and can any slavery be worse? A natural phenomenon of force, once so understood that it can be controlled, is it not as much a gift of God as rain and sunlight, and therefore part of the heritage of all mankind? Corporate wealth and corporate energy are doing much for mankind, despite the fact that of corporate shortcomings we hear just now more than we do of corporate benefactions. But corporate influence will have reached its most beneficent development when the wealth and activity and masterful management of the able men who wield it are united to the knowledge and skill of their technical staff in not only discovering but publishing the truths of nature, which they may be agents in revealing. Nor are we oversanguine in believing that this high aspiration, if carried into practice, would not interfere with the lower motive of their existence, money-making.

Sir Michael Faraday is not the only worker in the field of practical science who has given the results of his labor unreservedly to the world. It is almost invidious to single out instances when so many distinguished and such a multitude of obscure toilers are working at the intricate problems of technology from sheer attachment to truth and without any thought of gain. But three notable names may be mentioned as representative of this noble army of the unselfish—our own Prof. Henry, Dr. Roentgen, and that devoted couple, whom we rank as one—for, as husband and wife, they were as united in love one of another as they were one in love of science—Mons. and Madame Curie. The Roentgen ray may have needed no patents, or patentable devices, or any business organization to push its beneficial applications, especially in the alleviation of

suffering humanity, but it would not have been difficult to concoct patents had Dr. Roentgen, before describing his discoveries, wished to make money out of them. And could the practical resources of radial activity be measured by dollars, what a fortune the bereaved widow would reap! But Prof. Roentgen enjoys a better harvest than royalties, and Madame Curie would not exchange for a mountain of gold the world's admiration and reverence for her husband's memory.

But to descend to a lower plane. If it is the fact that technical science has progressed of late with such unwonted speed through the co-operation of many workers, and that this co-operation has been made possible by the publication and exchange of ideas and experiences in the technical and scientific journals, would not our progress be even more rapid and thorough if all barriers of secrecy were broken down, and every encouragement were given to our technical workers to describe, in print and by conference, their notions and their actual experiments? This is the attitude of some, I may almost say of most, of our large concerns, but unfortunately it is not that of all. It is impossible to compare, as to efficiency and profit, works the gates of which are fast shut, and in which obscurity and secrecy are imposed and practiced, with those to which free admission is granted and in which freedom of information is encouraged. But the following reflections force themselves upon us in this connection. We know that very few technical papers issue from certain establishments; that on their officials silence is imposed; and that to these works inquisitive visitors are politely but peremptorily refused admission. There are not many such, but they are and have been very successful. But suppose that in imitation of their practice and regulations all were tempted to adopt it, so that the same policy became universal; what a sudden paralysis of industry would follow! Our secretaries would find it difficult to fill even their shrunken volumes of transactions with papers worth printing; our students would have to content themselves with the antiquated learning which their professors could supply; for there would be no more summer classes for practical work in mines, smelters and electrical factories, and the professors themselves would have to learn from old books. Every manu-

facturer and smelter would be obliged to bribe his neighbor's workmen and tempt away his neighbor's superintendents for information. As a result, before long, the very works which now find it so profitable, or think they do, to tap their friends' stock of knowledge and experience, and give nothing in return, would be driven in upon their own resources, and would undoubtedly then find them not so complete as they imagine. Of course, I am supposing an impossibility, because the spirit of intellectual freedom in our professions is too strong and too widespread to submit to such a tyranny, and because, before such darkness of ignorance had settled down on our great industries, the most pronounced advocates of secrecy would feel and acknowledge the ultimate consequences of concealment, and would become reformers. To-day they may have secrets, as valuable as Sir Henry's method of making plate glass and bronze powder, which it may pay them to conceal from their competitors, so long as they are admitted freely to their competitors' open shops; but even this is doubtful. For the spirit of secrecy is intimately allied with the spirit of suspicion and distrust; and the mind which is always suspecting is closed tight against the admission of fresh and fair impressions. Being jealous of others, it is prejudiced against their suggestions, and correspondingly prejudiced in favor of its own preconceptions. Progress therefore ceases.

This is a temper of mind foreign to a new country like ours, whose special industries have not been established long enough to wear grooves of rigid practice and sink into ruts of self-satisfied indifference. About the best correction we can apply to the growth of dry-rot is the banishment of secrecy. A curious instance of its blighting influence is seen in some of the older, not the newer, industries of the old world. The iron and steel-works of Europe have not kept pace with ours in size and production, but the ironmasters of Great Britain and Germany, in coke-making and in blast-furnace economies and in steel-making processes, have been our teachers. Nor have they been shy of communicating their improvements, or, through jealousy of our success, slow in adopting ours. No nobler monument of international comity in thought and experience exists than the seventy volumes of the *Proceedings of the Iron and Steel Institute*. And with few exceptions the

iron- and steel-works of England, Scotland, Germany and France are open to any accredited worker in the same domain. Yet before England was conspicuous as a maker of iron, she was famous the world over for her copper- and tin-production. But, between self-conceit and the inbred habits of trade-secrecy, her copper-smelting industry has fallen from its high estate. And it is not accidental, but linked as closely as any effect with its cause, that this decline is in great part the result of habits of secrecy which grew with the growth of age. At Swansea, every gate to the smelting-works is guarded, and as a result it has been as difficult for thought to escape out as for suggestions to find their way in. Swansea should still enjoy the leadership which her skilled labor, splendid coal and commanding maritime situation put within her reach; but she has preferred to gloat over her secrets behind closed doors rather than go out into the world in search of new business as well as technical methods, while also inviting the world to enter and exchange ideas with her. What is the consequence? New Zealand copper comes here to be refined, notwithstanding the first practical application of electrolysis to metals was made by Elkinton in England, and the Vivians adopted the Manhès method before Farrel introduced it into this country.

There are, however, of course, exceptions in England to this too prevalent habit of secrecy. To the works of the Rio Tinto at Port Talbot or of the Cape Copper Co. at Briton Ferry in South Wales, where metallurgical novelties have been tried, introductions are not refused. But the alliance of decay and suspicion in the instance I have given can hardly be accidental; and we may be sure that what is baneful in its effects in Europe is not likely to be beneficial here; for while the Atlantic separates continents it does not delimit the operation of laws.

In political life, vitality is maintained only when every man takes his full share as a debater in the discussion of political questions, and as a voter in the determination of state affairs. So in scientific and technical matters, the banishment of deceit, mystery and jealousy, and the freest admission of daylight by means of the unreserved diffusion of information through the press and personal intercourse, will instill into the whole body of workers a feeling of healthy rivalry, which,

while stimulating their mental activity, will correspondingly benefit the financial interests of their employers.

I have supposed an extreme case—that the example set by our few secretive establishments were followed by all. Let me imagine a more probable issue, such as, I believe, will result from the fellowship of knowledge and experience which Mr. Carnegie, in presenting to our national engineering societies their new home, urges them to cultivate—namely, that all our technical manufacturers will learn how they gain, and not lose, by encouraging their staff-officers to study their neighbors' methods, and by throwing open their own establishments, in turn, to the freest criticism of their competitors in trade. What will result? Nothing but advantage, I believe, to all whose wisdom and means have enabled them to provide themselves with the raw material of manufacture on advantageous terms, and to locate their works or factories at localities favorable for economical operation. Loss only to those who, in any case, ought to go out of business, because they have failed to secure the conditions essential to success! And, above all, benefit to the public, which, after all, is the finality we should always keep in view.

How, now, can these two cardinal conditions—financial success and public approval—be best attained? Unquestionably, by mutual help and the most unreserved publicity. In any branch of industry, no intelligent worker claims that he and his staff have attained either the utmost economy in operation or the most thorough acquaintance with all the reactions which enter into the processes which he practices. Each knows that hundreds of other intelligent and well-informed men are eagerly at work on the solution of the same problem. Some may be a little cleverer than others, and some may have made a little more progress in certain lines than their co-workers. But this discrepancy will not necessarily continue; for the clever fellow is picked up by rival works, the secret so carefully guarded leaks out, and the disturbed average of paid ability and of stock of knowledge is restored. But if the companies and their staff are unwilling unreservedly to pool their knowledge and experience, the advantage of making into one great stock such accumulated experience and knowledge of these hundreds of workers is forfeited. With certain reservations,

and by special permission, many of our larger establishments, in all or in certain departments, are freely open to each other's technical officers; but instead of being admitted upon sufferance, they should be invited in, with full liberty to study processes and test machinery; for assuredly the host would benefit as much as the guests by the discussion which would follow such unreserved exchange of ideas and comparisons of appliances and methods.

I have referred to certain limitations to publicity. One, undoubtedly, is costs. Under our present economic system, no manufacturer or miner or metallurgist cares to give away his costs, and that for very obvious reasons. What they are may be inferred, but professional courtesy forbids direct inquiry into that delicate subject. This restriction, however, need not interfere with unstinted technical freedom of intercourse. There is, moreover, another judicious limitation to publicity. Most of our largest concerns are incorporated and financed as joint-stock organizations, in which thousands of technically ignorant and helpless shareholders are interested. Unquestionably, indiscriminate admission to works and mines must be refused, for, unfortunately, there would be visitors who, if admitted, after the visit would tell remarkable stories, from actual observation, with the view to affect the value of stocks. But such restrictions do not affect the main proposition that mercantile concerns of every class, depending for success on technical knowledge and skill, would gain by the removal of restraint on the thought and action of their technical staff.

I am not blind to the fact that the same object is sought to be attained by the consolidation of many works under one organization, or by the encouragement of friendly financial co-operation among even competing companies; but this tendency to consolidation has not yet succeeded in obliterating competition, and will not as long as there are active, intelligent men among us, who prefer to rule rather than to be ruled, and to manage their own business rather than have it managed for them.

On the benefits or disadvantages of the present movement towards consolidation of works and the combination of capital in large industrial undertakings, there is, and will be, of course, considerable diversity of opinion. That competition is wasteful and is encumbered with other evils few will deny; that it



has a keenly stimulating effect all will admit. Yet it remains to be determined whether a board of absentee managers and paid officials will be a compensating substitute for the ambitions, personal pride and tireless energy and skill of the individuals who have built up great works which they may have seen, perhaps reluctantly, absorbed into a combination. There are, apart from the political and sociological aspects of the present consolidation tendency, technical and economical conditions which force themselves upon the consideration of those of us under whose management works have grown from small to large dimensions. The difficulty of maintaining a high standard of quality as the demand is made for enormously increased production is urgently presenting itself both to the management and to the public. And it is doubtful whether, after expansion has reached the point where administration charges become light, there is actual economy in unlimited expansion; and whether the most skillful and closely managed corporate organization can replace the personal supervision of a single mind. But what immediately concerns us in the present discussion is the dangerous temptation to adopt secretive methods by very large corporations.

The larger the combination grows the more sensitive will the management be lest business and trade secrets which they possess, or think they possess, be revealed by subordinate officers. The imposition, therefore, of strict rules of silence on all except those in supreme command is likely to result. If the absorption of any one class of our national resources should pass under the control of any one organization, the technical knowledge necessary to the development of that particular resource would be of interest to that organization alone, and the risks of publicity, and therefore the evils of secrecy, would become a merely academic question. This dangerous point, under our present industrial system, will probably not be reached; for state socialism, to which concentration steadily approaches, would be the inevitable alternative and would be adopted before the other alternative had been attained. But it must be to the management of those enormous consolidations a grave consideration how they can give such latitude to the members of their staff as will produce that healthy self-reliance which comes from freedom of speech and freedom of opinion, with-

out endangering the tremendous financial interests for which they are responsible. Whatever individual difference of opinion on this subject there may be among the managers of the great industrial establishments, there is not any difference of opinion in the country at large; and public opinion has to be consulted. Therefore, would it not be safer and better for the interests of the shareholders to adopt the policy of freedom which I have outlined, and thus placate the public? For the growing public anxiety, amounting to animosity and suspicion, against our big corporations would be allayed if it were apparent that the technical officials of the small concern had at least the right of knowing what the big concern was doing, and the big official did not arrogate to himself the possession of exclusive knowledge and exclusive skill. From the point of view of public policy, the question is one well worthy of consideration; for it is coming about that not only railroads, as public highways, but all large corporations utilizing the country's natural products and converting them into necessary objects of trade, will pass under closer legislative scrutiny and public criticism in the future than they have in the past—a necessary limitation, which will become more exacting the larger the corporations grow—if the tendency to growth continues.

While unquestionably dangers can be foreseen as arising out of these great industrial aggregations—not only of capital but of industrial energy—dangers technical, social and political—there are also great possibilities of good. One of the benefits may justly be claimed to reside in the large funds that are thus rendered available for technical research, from which the public derives benefit indirectly, even if the results are not published. But if we could banish secrecy; if every industrial establishment of any magnitude, which is in its own interest carrying on technical research, should encourage its technical staff to confer freely with the members of every other technical staff, would not the sciences and arts progress far more rapidly than if one huge organization controlled a given industry? All our principal metallurgical and chemical concerns have laboratories, and carry on investigations and make experiments, generally on a large working scale; and surely the advancement of technological science can be better attained in a number of such laboratories than if there were fewer or

in only one. There is keener competition of wits when many brains are working independently. The friction of honest rivalry is a force not to be despised. The stimulus of ambition is sure to be stronger in smaller than in large consolidated workshops. The air in such laboratories is freer and purer than when men are working in the stifling atmosphere of secrecy. I believe that such a consolidation of mind and high impulses would carry us further and faster along the road of human progress than all the money that all the trusts could appropriate for the advancement of technical knowledge.

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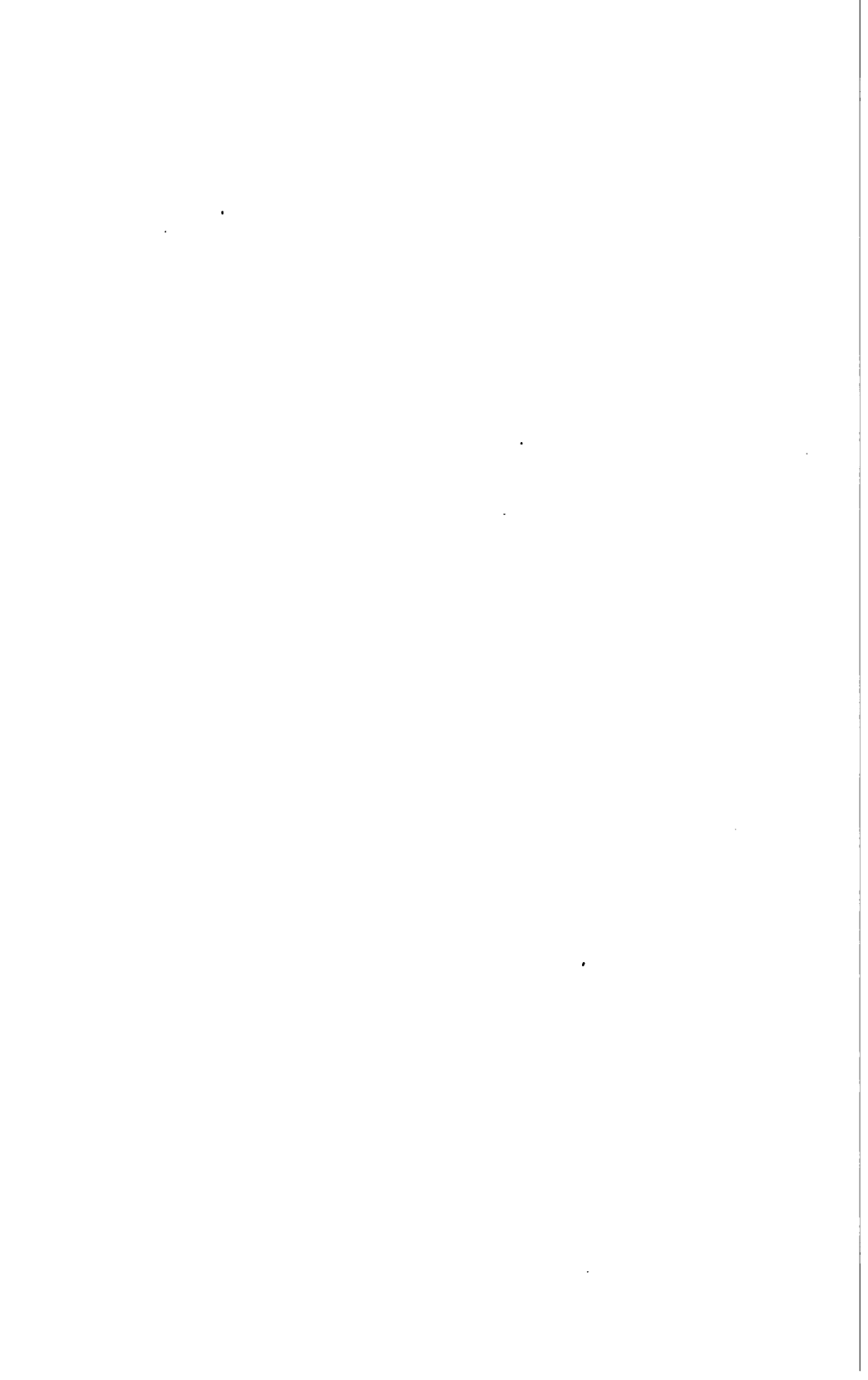
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## INDEX OF TITLES AND AUTHORS.

Nos. 13 to 18, FOR THE YEAR 1907.

---

BULLETIN No. 13, JANUARY,	1907 ( XIII )
BULLETIN No. 14, MARCH,	1907 ( XIV )
BULLETIN No. 15, MAY,	1907 ( XV )
BULLETIN No. 16, JULY,	1907 ( XVI )
BULLETIN No. 17, SEPTEMBER,	1907 ( XVII )
BULLETIN No. 18, NOVEMBER,	1907 ( XVIII )



## INDEX OF TITLES AND AUTHORS FOR THE YEAR 1907.

---

- A Study in Refining and Overpoling Electrolytic Copper. By H. B. HALLOWELL, R. HAYDEN, and H. O. HOFMAN, xiv, 275.
- An Early Instance of "Blowing-In" Without "Scaffolding-Down." By FRANK FIRMSTONE, xiv, 329.
- AYRES, W. S. Deutschman's Cave, near Banff, B. C., Canada, xiii, 93.
- BANCROFT, GEORGE J. The Formation and Enrichment of Ore-Bearing Veins, xv, 499.
- BANKS, E. G. Grinding in Tube-Mills at the Waihi Gold-Mine, Waihi, New Zealand, xiii, 63.
- Barite Associated with Iron-Ore in Pinar del Rio Province, Cuba. By CHARLES CATLETT, xvi, 623.
- BEUTTER, F., HOWE, H. M., and HUNT, R. W. *Discussion of MR. HOWE's paper, Piping and Segregation in Steel Ingots*, xvi, 609.
- Bibliography of Injuries to Vegetation by Furnace Gases. By PERSIFOR FRAZER, xv, 399.
- Biographical Notice of William George Neilson. By JOHN BIRKINBINE, xvi, 653.
- Biographical Notices of 1906, xvi, 657.
- BIRKINBINE, JOHN. Biographical Notice of WILLIAM GEORGE NEILSON, xvi, 653.
- Blast-Furnace Practice. By T. F. WITHERBEE, xv, 523.
- Blow-Holes in Steel Ingots. By E. von MALTITZ, xvii, 691.
- BROWN, R. GILMAN. The Vein-System of the Standard Mine, Bodie, California, xvi, 587.
- Butters Filter. By MARK R. LAMB, xiii, 67.
- CATLETT, CHARLES. Barite Associated with Iron-Ore in Pinar del Rio Province, Cuba, xvi, 623.
- CATLETT, CHARLES. Quantitative Field-Test for Magnesia in Cement Rock and Limestone, viii, 947.

- CAYPLESS, W. S., HARRINGTON, E. E., and HOFMAN, H. O. The Constitution of Ferro-Cuprous Sulphides, xiii, 25.
- Chlorination of Gold-Ores; Laboratory Tests. By A. L. SWEETSER, xvii, 747.
- Chronology of Lead Mining in the United States. By W. R. INGALLS, xviii, 979.
- CLERC, F. L. The Ore-Deposits of the Joplin Region, Missouri, xiv, 353.
- Coal-Briquetting in the United States. By EDWARD A. PARKER, xvii, 789.
- COLBY, ALBERT LADD. Reply to the *Discussion* of MR. COLBY's paper, Comparison of American and Foreign Rail Specifications with a Proposed Standard Specification to Cover American Rails Rolled for Export, xiv, 345.
- Constitution of Ferro-Cuprous Sulphides. By W. S. CAYPLESS, E. E. HARRINGTON, and H. O. HOFMAN, xiii, 25.
- Cyanidation of Raw Pyritic Concentrates. By F. C. SMITH, xiii, 1.
- DAGGETT, ELLSWORTH. The Extraordinary Faulting at the Berlin Mine, Nevada, xiv, 331.
- DE KALB, COURTENAY. Geology of the Exposed Treasure Lode, Mojave, California, xiii, 15.
- Deutschman's Cave, near Banff, B. C., Canada. By W. S. AYRES, xiii, 93.
- DOUGLAS, JAMES. Secrecy in the Arts, xviii, 1001.
- DUFF, E. J. (and others). Gas-Engine Practice. *Discussion* of MR. HUBERT's paper, The Design of Blast-Furnace Gas-Engines in Belgium; MR. REINHARDT's paper, The Application of Large Gas-Engines in the German Iron and Steel Industries; and MR. WESTGARTH's paper, Notes on Large Gas-Engines in the German Iron and Steel Industries, xiii, 79.
- Early Instance of "Blowing-In" Without "Scaffolding-Down." By FRANK FIRMSTONE, xiv, 829.
- Effect of High Litharge in the Crucible Assay for Silver. By RICHARD W. LODGE, xvii, 783.
- Electric Air-Drill. By WILLIAM L. SAUNDERS, xviii, 991.
- Extraordinary Faulting at the Berlin Mine, Nevada. By ELLSWORTH DAGGETT, xiv, 331.

- FAY, ALBERT HILL. Geology and Mining of the Tin-Deposits of Cape Prince of Wales, Alaska, xvii, 769.
- FIRMSTONE, FRANK. An Early Instance of "Blowing-In" Without "Scaffolding-Down," xiv, 329.
- Fluorite and Barite in Tennessee. By THOMAS L. WATSON, xiii, 77.
- Formation and Enrichment of Ore-Bearing Veins. By GEORGE J. BANCROFT, xv, 499.
- FRAZER, PERSIFOR. Bibliography of Injuries to Vegetation by Furnace-Gases, xv, 399.
- FRAZER, PERSIFOR. Bibliography of Injuries to Vegetation by Furnace-Gases. Supplementary Note, xvi, 625.
- FRAZER, PERSIFOR. Search for the Causes of Injury to Vegetation in an Urban Villa Near a Large Industrial Establishment, xv, 377.
- FREIR, W. E. (and others). *Discussion* of MR. COLBY's paper, Comparison of American and Foreign Rail Specifications, with a Proposed Standard Specification to Cover American Rails Rolled for Export, xiii, 113.
- Gas-Engine Practice. *Discussion* of MR. HUBERT's paper, The Design of Blast-Furnace Gas-Engines in Belgium; MR. REINHARDT's paper, The Application of Large Gas-Engines in the German Iron and Steel Industries; and MR. WESTGARTH's paper, Notes on Large Gas-Engines in the German Iron and Steel Industries, xiii, 79.
- Geology and Mining of the Tin-Deposits of Cape Prince of Wales, Alaska. By ALBERT HILL FAY, xvii, 769.
- Geology of the Virginia Barite Deposits. By THOMAS L. WATSON, xviii, 953.
- Geological Relations of the Scandinavian Iron-Ores. By HJALMAR SJÖGREN, xviii, 877.
- Geology of the Exposed Treasure Lode, Mojave, California. By COURTENAY DE KALB, xiii, 15.
- GIBB, ALLAN. *Discussion* of paper by MESSRS. GIBB and PHILP, The Constitution of Mattes Produced in Copper-Smelting, xiii, 139.
- GREINER, ADOLPH (and others). Gas-Engine Practice. *Discussion* of MR. HUBERT's paper, The Design of Blast-Furnace Gas-Engines in Belgium; MR. REINHARDT's paper,



- The Application of Large Gas-Engines in the German Iron and Steel Industries; and MR. WESTGARTH's paper, Notes on Large Gas-Engines in the German Iron and Steel Industries, xiii, 79.
- Grinding in Tube-Mills at the Waihi Gold-Mine, Waihi, New Zealand. By E. G. BANKS, xiii, 63.
- HADFIELD, R. A. (and others). *Discussion* of MR. COLBY's paper, Comparison of American and Foreign Rail Specifications, with a Proposed Standard Specification to Cover American Rails Rolled for Export, xiii, 113.
- HALLOWELL, H. B., HAYDEN, R., and HOFMAN, H. O. A Study in Refining and Overpoling Electrolytic Copper, xiv, 275.
- HAMILTON, JAMES (and others). Gas-Engine Practice. *Discussion* of MR. HUBERT's paper, The Design of Blast-Furnace Gas-Engines in Belgium; MR. REINHARDT's paper, The Application of Large Gas-Engines in the German Iron and Steel Industries; and MR. WESTGARTH's paper, Notes on Large Gas-Engines in the German Iron and Steel Industries, xiii, 79.
- HARBORD, F. W. (and others). *Discussion* of MR. COLBY's paper, Comparison of American and Foreign Rail Specifications, with a Proposed Standard Specification to Cover American Rails Rolled for Export, xiii, 113.
- HARRINGTON, E. E., CAYPLESS, W. S., and HOFMAN, H. O. Constitution of Ferro-Cuprous Sulphides, xiii, 25.
- HAVARD, F. T. (and others). *Discussion* of MR. LEE's paper, The Gas-Producer as an Auxiliary in Iron Blast-Furnace Practice, xv, 537.
- HAYDEN, R., HALLOWELL, H. B., and HOFMAN, H. O. A Study in Refining and Overpoling Electrolytic Copper, xiv, 275.
- HILDAGE, H. T. Mining Operations in New York City and Vicinity, xv, 461.
- HOFMAN, H. O., RAYNOLDS, R. P., and WELLS, A. E. Laboratory Experiments in Lime-Roasting a Galena Concentrate, xiii, 37.
- HOFMAN, H. O., HALLOWELL, H. B., and HAYDEN, R. A Study in Refining and Overpoling Electrolytic Copper, xiv, 275.
- HOWE, H. M. *Discussion* of MR. MATHEWSON's paper, Relative Elimination of Iron, Sulphur and Arsenic in Bessemerizing Copper-Mattes, xvi, 689.

- HOWE, H. M. Piping and Segregation in Steel Ingots, xiv, 169.
- HOWE, H. M. Roasting of the Argentiferous Cobalt-Nickel Arsenides of Temiskaming, Ontario, Canada, xiii, 58.
- HOWE, H. M., and STOUGHTON, BRADLEY. The Influence of the Conditions of Casting on Piping and Segregation, as Shown by Means of Wax Ingots, xvi, 561.
- HUNT, ROBERT W. and KERLEN, KURT. *Discussion* of Mr. YORK's paper, Improvements in Rolling Iron and Steel, xiii, 133.
- HUNT, ROBERT W. (and others). *Discussion* of Mr. COLBY's paper, Comparison of American and Foreign Rail Specifications, with a Proposed Standard Specification to Cover American Rails Rolled for Export, xiii, 113.
- Index of Titles and Authors, 1905, xiii, 147.
- Index of Titles and Authors, 1906, xiii, 161.
- Index of Titles and Authors, 1907, xviii, 1019.
- Influence of the Conditions of Casting on Piping and Segregation as Shown by Means of Wax-Ingots. By H. M. HOWE and BRADLEY STOUGHTON, xvi, 561.
- INGALLS, W. R. Chronology of Lead Mining in the United States, xviii, 979.
- JOHNSON, J. E., JR. *Discussion* of Mr. MEISSNER's paper, Notes on the Gayley Dry-Air Blast Process, xvi, 575.
- JOHNSON, WOOLSEY McA. Physical Factors in the Metallurgical Reduction of Zinc Oxide, xvii, 757.
- KEMP, JAMES F. The White Knob Copper-Deposits, xiv, 301.
- KENNEDY, JULIAN E. (and others). Gas-Engine Practice. *Discussion* of Mr. HUBERT's paper, The Design of Blast-Furnace Gas-Engines in Belgium; Mr. REINHARDT's paper, The Application of Large Gas-Engines in the German Iron and Steel Industries; and Mr. WESTGARTH's paper, Notes on Large Gas-Engines in the German Iron and Steel Industries, xiii, 79.
- KENNEY, E. F. (and others). *Discussion* of Mr. COLBY's paper, Comparison of American and Foreign Rail Specifications with a Proposed Standard Specification to Cover American Rails Rolled for Export, xiii, 113.
- KENT, WILLIAM (and others). Gas-Engine Practice. *Discussion* of Mr. HUBERT's paper, The Design of Blast-Furnace Gas-Engines in Belgium; Mr. REINHARDT's paper, The

Application of Large Gas-Engines in the German Iron and Steel Industries; and MR. WESTGARTH's paper, Notes on Large Gas-Engines in the German Iron and Steel Industries, xiii, 79.

KERLEN, KURT, and HUNT, ROBERT W. *Discussion* of MR. YORK's paper, Improvements in Rolling Iron and Steel, xiii, 133.

Laboratory Experiments in Lime-Roasting a Galena Concentrate. By H. O. HOFMAN, R. P. RAYNOLDS, and A. E. WELLS, xiii, 37.

LAMB, MARK R. The Butters Filter, xiii, 67.

LAMBERTON, THOMAS (and others). *Discussion* of MR. COLBY's paper, Comparison of American and Foreign Rail Specifications, with a Proposed Standard Specification to Cover American Rails Rolled for Export, xiii, 113.

LANE, ALFRED C., and HOWE, H. M. *Discussion* of MR. HOWE's paper, Piping and Segregation in Steel Ingots, xvii, 765.

LODGE, RICHARD W. The Effect of High Litharge in the Crucible-Assay for Silver, xvii, 733.

MALTITZ, E. VON. Blow-Holes in Steel Ingots, xvii, 691.

MATHEWSON, E. P. Relative Elimination of Iron, Sulphur and Arsenic in Bessemerizing Copper-Mattes, xiii, 7.

Mining Operations in New York City and Vicinity. By H. T. HILDAGE, xv, 461.

NIGOND, M. (and others). *Discussion* of MR. COLBY's paper, Comparison of American and Foreign Rail Specifications, with a Proposed Standard Specification to Cover American Rails Rolled for Export, xiii, 113.

Occurrence of Nickel in Virginia. By THOMAS L. WATSON, xvii, 829.

Ore-Deposits of the Joplin Region, Missouri. By F. L. CLERC, xiv, 353.

PACKARD, GEORGE A. *Discussion* of MR. HOFMAN's paper, Laboratory Experiments in Lime-Roasting a Galena Concentrate, xvi, 603.

PALMER, C. S. R. (and others). *Discussion* of MR. COLBY's paper, Comparison of American and Foreign Rail Specifications, with a Proposed Standard Specification to Cover American Rails Rolled for Export, xiii, 113.

- PARKER, EDWARD A. Coal-Briquetting in the United States, xvii, 789.
- Physical Factors in the Metallurgical Reduction of Zinc Oxide. By WOOLSEY McA. JOHNSON, xvii, 757.
- Piping and Segregation in Steel Ingots. By H. M. HOWE, xiv, 169.
- PORTER, JOHN J. Zinc Oxide in Iron-Ores, and the Effect of Zinc in the Iron Blast-Furnace, xvii, 739.
- Presence of Gold and Silver in Deep Sea Dredgings. By LUTHER WAGONER, xviii, 977.
- Present Source and Uses of Vanadium. By J. KENT SMITH, xvii, 727.
- PRICE-WILLIAMS, THOMAS (and others). *Discussion* of MR. COLBY's paper, Comparison of American and Foreign Rail Specifications, with a Proposed Standard Specification to Cover American Rails Rolled for Export, xiii, 113.
- Proceedings of the Ninety-second Meeting, New York, April, 1907, xv, 541.
- Proceedings of the Ninety-third Meeting, Toronto, July, 1907, xvii, 847.
- PULLON, J. T. (and others). *Discussion* of MR. LEE's paper, The Gas-Producer as an Auxiliary in Iron Blast-Furnace Practice, xv, 537.
- Quantitative Field-Test for Magnesia in Cement Rock and Limestone. By CHARLES CATLETT, xviii, 947.
- RAYMOND, R. W. (and others). Gas-Engine Practice. *Discussion* of MR. HUBERT's paper, The Design of Blast-Furnace Gas-Engines in Belgium; MR. REINHARDT's paper, The Application of Large Gas-Engines in the German Iron Steel Industries; and MR. WESTGARTH's paper, Notes on Large Gas-Engines in the German Iron and Steel Industries, xiii, 79.
- RAYNOLDS, R. P., HOFMAN, H. O. and WELLS, A. E. Laboratory Experiments in Lime-Roasting a Galena Concentrate, xiii, 37.
- READ, T. T., and SULLIVAN, E. C. *Discussion* of MR. READ's paper, The Secondary Enrichment of Copper-Iron Sulphides, xiii, 143.
- Relative Elimination of Iron, Sulphur and Arsenic in Bessemerizing Copper-Mattes. By E. P. MATHEWSON, xiii, 7.

- Reply to *Discussion* of MR. COLBY'S paper, Comparison of American and Foreign Rail Specifications, with a Proposed Standard Specification to Cover American Rails Rolled for Export. By A. L. COLBY, xiv, 345.
- RICHARDS, E. WINDSOR (and others). *Discussion* of MR. COLBY'S paper, Comparison of American and Foreign Rail Specifications, with a Proposed Standard Specification to Cover American Rails Rolled for Export, xiii, 113.
- RICHARDS, ROBERT H. Velocity of Galena and Quartz Falling in Water, xv, 435.
- RICHARDS, ROBERT H. The Wilfley Table, xvi, 627.
- Roasting of the Argentiferous Cobalt-Nickel Arsenides of Temiskaming, Ontario, Can. By H. M. HOWE, viii, 53.
- ROBINSON, MARK (and others). Gas-Engine Practice. *Discussion* of MR. HUBERT'S paper, The Design of Blast-Furnace Gas-Engines in Belgium; MR. REINHARDT'S paper, The Application of Large Gas-Engines in the German Iron and Steel Industries; and MR. WESTGARTH'S paper, Notes on Large Gas-Engines in the German Iron and Steel Industries, xiii, 79.
- SAUNDERS, WILLIAM L. The Electric Air-Drill, xviii, 991.
- SAUVEUR, ALBERT (and others). *Discussion* of MR. COLBY'S paper, Comparison of American and Foreign Rail Specifications, with a Proposed Standard Specification to Cover American Rails Rolled for Export, xiii, 113.
- SAUVEUR, ALBERT. *Discussion* of MR. CORSON'S paper, Heat-Treatment of Steels Containing Fifty-Hundredths and Eighty-Hundredths Per Cent. of Carbon, xiii, 137.
- Search for the Causes of Injuries to Vegetation in an Urban Villa near a Large Industrial Establishment. By PERSIFOR FRAZER, xv, 377.
- Secrecy in the Arts. By JAMES DOUGLAS, xviii, 1001.
- SJÖGREN, HJALMAR. The Geological Relations of the Scandinavian Iron-Ores, xviii, 877.
- SMITH, F. C. The Cyanidation of Raw Pyritic Concentrates, xiii, 1.
- SMITH, J. KENT. The Present Source and Uses of Vanadium, xvii, 727.
- STEAD, J. E. (and others). *Discussion* of MR. COLBY'S paper, Comparison of American and Foreign Rail Specifications,

- with a Proposed Standard Specification to Cover American Rails Rolled for Export, xiii, 118.
- STOUGHTON, BRADLEY, and HOWE, H. M. The Influence of the Conditions of Casting on Piping and Segregation, as Shown by Means of Wax Ingots, xvi, 561.
- Study in Refining and Overpoling Electrolytic Copper. By H. B. HALLOWELL, R. HAYDEN, and H. O. HOFMAN, xiv, 275.
- SULLIVAN, E. C., and READ, T. T. *Discussion* of MR. READ's paper, The Secondary Enrichment of Copper-Iron Sulphides, xiii, 143.
- SWEETSER, A. L. Chlorination of Gold-Ores; Laboratory Tests, xvii, 747.
- TANNETT-WALKER, A. T. (and others). Gas-Engine Practice. *Discussion* of MR. HUBERT's paper, The Design of Blast-Furnace Gas-Engines in Belgium; MR. REINHARDT's paper, The Application of Large Gas-Engines in the German Iron and Steel Industries; and MR. WESTGARTH's paper, Notes on Large Gas-Engines in the German Iron and Steel Industries, xiii, 79.
- THWAITE, B. H. (and others). Gas-Engine Practice. *Discussion* of MR. HUBERT's paper, The Design of Blast-Furnace Gas-Engines in Belgium; MR. REINHARDT's paper, The Application of Large Gas-Engines in the German Iron and Steel Industries; and MR. WESTGARTH's paper, Notes on Large Gas-Engines in the German Iron and Steel Industries, xiii, 79.
- TURNER, PROFESSOR (and others). Gas-Engine Practice. *Discussion* of MR. HUBERT's paper, The Design of Blast-Furnace Gas-Engines in Belgium; MR. REINHARDT's paper, The Application of Large Gas-Engines in the German Iron and Steel Industries; and MR. WESTGARTH's paper, Notes on Large Gas-Engines in the German Iron and Steel Industries, xiii: 79.
- Vein System of Standard Mine, Bodie, California. By R. GILMAN BROWN, xvi, 587.
- VERSCHOYLE, W. D. The Verschoyle Pocket Transit, xvi, 617.
- Verschoyle Pocket Transit. By W. D. VERSCHOYLE, xvi, 617.
- WAGONER, LUTHER. The Presence of Gold and Silver in Deep Sea Dredgings, xviii, 977.
- WATSON, THOMAS L. Fluorite and Barite in Tennessee, xiii, 77.

- WATSON, THOMAS L. Geology of the Virginia Barite Deposits, xviii, 958.
- WATSON, THOMAS L. The Occurrence of Nickel in Virginia, xvii, 829.
- WEBSTER, WILLIAM R. (and others). *Discussion of MR. COLBY'S paper, Comparison of American and Foreign Rail-Specifications, with a Proposed Standard Specification to Cover American Rails Rolled for Export*, xiii, 118.
- WELLS, A. E., HOFMAN, H. O., and RAYNOLDS, R. P. Laboratory Experiments in Lime-Roasting a Galena Concentrate, xiii, 87.
- WITHERBEE, Blast-Furnace Practice, xv, 523.
- WITHERBEE, Blast-Furnace Practice; Supplementary Note, xvii, 845.
- Zinc-Oxide in Iron-Ores and the Effect of Zinc in the Iron Blast-Furnace. By JOHN J. PORTER, xvii, 739.

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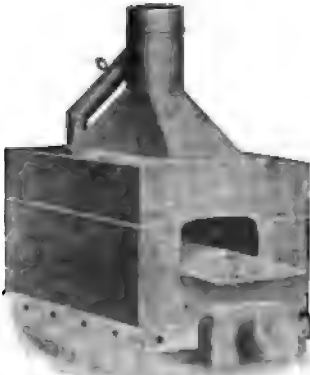
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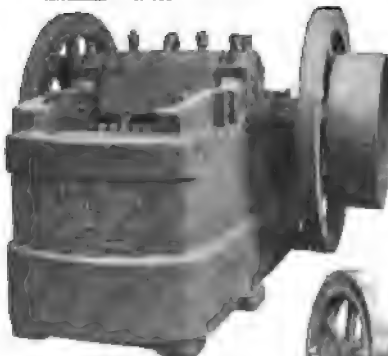
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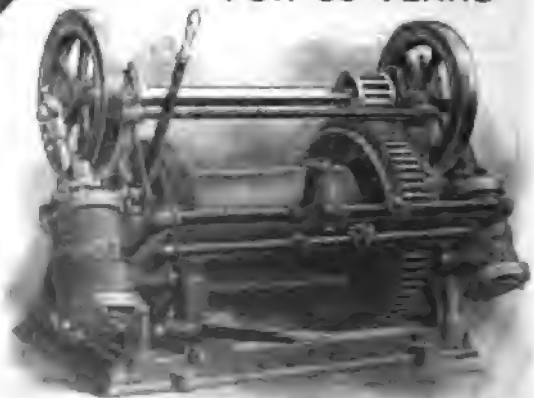
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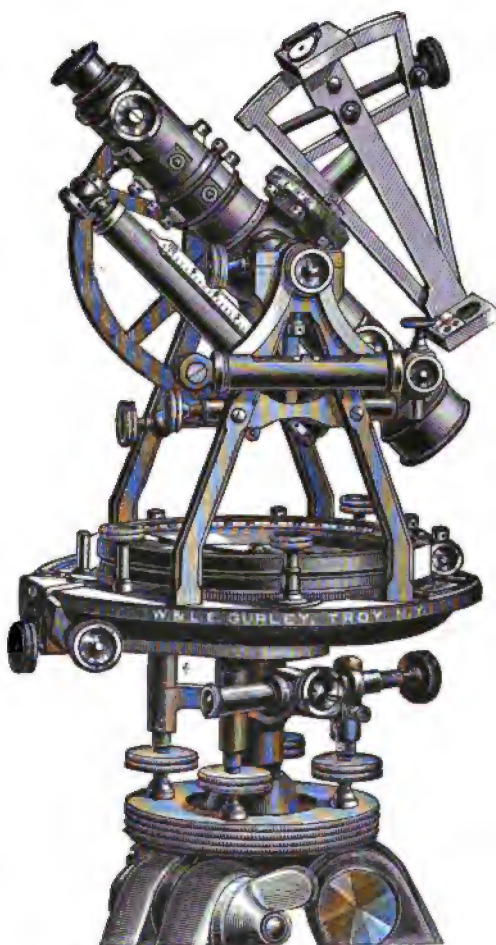
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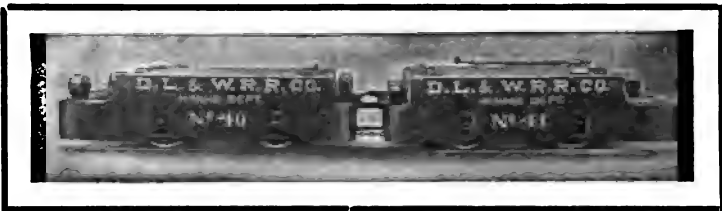
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